SCHOOL OF CIVIL ENGINEERING

INDIANA DEPARTMENT OF HIGHWAYS

JOINT HIGHWAY RESEARCH PROJECT
JHRP-84-13

ENGINEERING SOILS MAP OF BROWN COUNTY, INDIANA

Leo J. Frey, III

PURDUE UNIVERSITY

Final Report

ENGINEERING SOILS MAP OF BROWN COUNTY, INDIANA

To: H.L. Michael, Director
Joint Highway Research Project

July 3, 1984

Project: C-36-51B

From: R. D. Miles

File: 1-5-2-73

Attached is the Final Report on the "Engineering Soils Map of Brown County, Indiana." The map and report has been prepared by Mr. Leo F. Frey, Graduate Assistant on our staff under the direction of Professors Robert D. Miles and Charles W. Lovell.

This is the 72nd available county engineering soils map and report which has been completed by using aerial photography and available information. The map and report should be very useful in planning and developing engineering facilities in Brown County.

The Report is presented to the Board as a final report showing completion of the Brown County engineering soils mapping project.

Sincerely,

Robert D. Miles

Robert D. Miles

RDM/rrw

cc: A. G. Altschaeffl
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Final Report

ENGINEERING SOILS MAP OF BROWN COUNTY, INDIANA

by

Leo J. Frey, III
Graduate Assistant

Joint Highway Research Project

Project No: C-36-51B

File No: 1-5-2-73

Prepared as Part of an Investigation

Conducted by

Joint Highway Research Project
Engineering Experiment Station
Purdue University

In Cooperation with

Indiana Department of Highways

Purdue University
West Lafayette, Indiana
July 3, 1984

Acknowledgements

The author wishes to thank Professor C. W. Lovell, who provided technical guidance and encouragement. He is especially grateful to Professor R. D. Miles for the constant assistance he gave during the mapping of Brown County. He also wishes to acknowledge Professor H. L. Michael, Director of the Joint Highway Research Project, and other members of the JHRP Board for their continued support of the county soil mapping project.

A special words of thanks to the members of the Brown County Survey, the staff of engineers at the IDOH, Materials and Testing Division (especially Mr. Sisiliano), and to Mr. Web Harden of the Brown County Highway Department. They gave freely of their time and effort in making much of the data in this report accessible.

In addition, the author is indebted to other students with whom he had the pleasure to work on this project, including Frank Adams, Andy Huang, and especially Ed Gefell for his friendship and technical assistance. Special recognition should be given to the draftpersons, Patty Cullen and Debbie Gonzales, for their excellent work, and finally to Dawn Burk Leverknight and Rita Wolf for their secretarial skills.

Abstract

The following report entitled, "Engineering Soils Map of Brown County, Indiana," contains very useful information for the planning and design of engineering facilities. The attached map depicts the locations of the engineering soil-parent material associations. The first part of the report gives general geologic, drainage, and topographic data concerning Brown County. The engineering properties and descriptions of the soils formed over their respective landform is given (e.g.seasonal groundwater table depths, AASHTO classification of soil texture, liquid and plastic limits, etc).

The second portion of this report describes many of the geotechnical problems found in Brown County. Based upon data from the preceding section and field investigations, the problems are identified and examined for cause of origin. This report represents an effort to alert the field engineer who is not familar with the area to actual field conditions and potential hazards.

Table of Contents

Engineering Soils Map
of
Brown County, Indiana

Introduction

The engineering soils map of Brown County, Indiana which accompanies this report was prepared primarily by airphoto interpretation techniques using accepted principles of observation (1)*. Several field trips were made to correlate aerial photographic patterns with surface soil texture and during these expeditions, evidence was collected on geotechnical problems which the county has experienced. The two sets of aerial photography used had a scale of 1:20,000, were taken in August, 1939 and June, 1960 by the Department of Agriculture and were purchased from that agency.

Standard symbols developed by the staff of the Airphoto Interpretation Laboratory, School of Civil Engineering, Purdue University, were employed to delineate landform-parent material associations and surface soil textures. The text of this report includes a general description of the study area, descriptions of the engineering soil types, and a discussion of the engineering problems associated with and the uses of the soils and bedrock found in Brown County, Indiana.

Soil samples were collected to verify the soil profiles

* Note: numbers in parentheses refer to items in References.

shown on the map. The profiles were constructed from information obtained from the Brown County Agricultural Soil Survey (2,3), field sampling, roadway soil data along various state highways and site investigations borings.

General

Brown County is located in south-central Indiana (See Figure 1). The county seat, Nashville (population 703), is located 39 miles south of Indianapolis and 6.5 miles west of the Bartholomew county line along the north fork of Salt Creek. Total county population was 9,057, as reported in the 1970 census (4). The county is rectangular in shape. Brown County covers 324 square miles or 207,360 acres and is bordered by five counties; Johnson to the north, Morgan to the northwest, Monroe to the west, Jackson to the south, and Bartholomew to the east.

According to the 1938 county agricultural soil report (2), only 18 percent or 37,542 acres were available for farm crops due to the rugged terrain. This figure has remained approximately constant over the last 45 years. A large portion of the farmland is confined to the glaciated areas located in the northern third of the county. The shale and sandstone uplands are generally timber-covered.

Federal and state agencies purchased large areas in the southern and western parts of the county for the Brown County State Game Preserve (11,400 acres) and Pleasant Run National

Figure 1. Location of Brown County.

Forest (7,246 acres). The latter is under the jurisdiction of the U.S. Forest Service. The United States Air Force maintains a reservation, Camp Atterbury, in the northeastern portion of the county.

Climate

The climate of Brown County is continental, humid and temperate with hot summers and cold winters. The mean annual precipitation at Hickory Hill was 41 inches between the years 1922-1925 (2). Climatological summaries (41) from the closest recording stations (Bloomington to the west and Columbus to the east), are included in this report for comparison and interpolation (see Tables 1 and 2).

The rugged topography sometimes results in sharp temperature variation over short distances. Winter temperatures were recorded (2) as low as -20° F with a low mean of 30° F for the month of December. Average snowfall was around 13 inches. Severe windstorms or thunderstorms are uncommon and tornadoes are rare. A high of 108° F was recorded with a mean high of 74° F.

Drainage Features

Brown County lies within the White River drainage basin of Indiana (5). Regional drainage is to the west. The drainage system in the uplifted sandstone - shale region is in an early state of maturity, while that in the Illinoian till in the northern

U.S. DEPARTMENT OF COMMERCE
ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION
IN COOPERATION WITH DEPARTMENT OF GEOLOGY, INDIANA UNIVERSITY
CLIMATOGRAPHY OF THE UNITED STATES NO. 20 - 12

LATITUDE 39° 11' N.
LONGITUDE 86° 31' W.
ELEVATION (ground) 830 Ft.

STATION BLOOMINGTON, INDIANA

CLIMATOLOGICAL SUMMARY

Table 1

MEANS AND EXTREMES FOR PERIOD 1896-1968 (a)

Month	Temperature (°F) Means: Daily maximum	Daily minimum	Monthly	Extremes: Record highest	Year	Record lowest	Year	Degree days ** Heating	Cooling	Precipitation Totals (Inches): Mean	Greatest daily	Year	Snow, Sleet: Mean	Maximum monthly	Year	Greatest daily	Year	Mean number of days: Precip. (inch) .10+	.50+	1.00+	Temperatures Max. 90° and above	32° and below	Min. 32° and below	0° and below	Month
(a)	71	71	71	71		72		16	71	71	72		63	38		38		17	17	17	32	32	32	32	
Jan.	40.1	21.9	31.0	78	23 '50	-20	12 '18	1053	0	3.81	3.28	21 '37	5.7	8.3	1939	7.5	1937	8	3	1	0	8	23	2	Jan.
Feb.	42.3	23.1	32.7	79	10 '32	-20	12 '99	872	0	2.87	2.82	13 '50	4.6	12.0	1960	6.5	1960	8	3	1	0	3	22	*	Feb.
Mar.	52.7	32.1	42.4	86	23 '10	- 2	5 '43	704	0	4.59	3.56	25 '13	2.7	11.0	1917	6.0	1960	9	3	1	0	1	16	*	Mar.
Apr.	65.1	42.6	53.9	91	24 '25	17	1 '23	297	0	3.92	2.59	11 '46	0.3	4.5	1962	4.5	1962	9	3	1	0	0	3	0	Apr.
May	75.6	52.2	63.9	97	31 '34	29	10 '66	108	90	4.39	3.30	4 '58	0	0		0		9	3	1	1	0	*	0	May
June	84.0	61.2	72.6	103	28 '11	38	1 '10	10	233	4.21	4.83	23 '40	0	0		0		8	3	1	8	0	0	0	June
July	88.1	64.9	76.4	110	14 '36	46	28 '11	0	360	3.70	4.23	16 '10	0	0		0		7	4	1	13	0	0	0	July
Aug.	86.6	63.2	74.9	104	7 '18	41	31 '15	3	307	3.46	4.88	15 '41	0	0		0		5	2	1	12	0	0	0	Aug.
Sept.	80.4	56.3	68.4	103	8 '22	28	30 '99	47	171	3.13	3.40	2 '11	0	0		0		5	2	1	3	0	*	0	Sept.
Oct.	69.4	44.3	57.0	98	4 '54	17	29 '25	248	31	2.93	4.02	6 '10	T	0.2	1925	T	1954	6	1	*	*	0	3	0	Oct.
Nov.	54.0	34.3	43.2	84	1 '50	- 2	30 '58	601	0	3.27	3.16	3 '56	0.9	7.3	1913	6.2	1950	7	2	1	0	1	13	*	Nov.
Dec.	41.6	24.7	33.2	71	11 '48	-16	28 '24	983	0	3.34	2.58	31 '32	4.3	15.0	1963	7.0	1963	8	3	1	0	6	24	1	Dec.
Year	63.2	43.3	54.4	110	7/14+ 1936	-20	1/12 1918+	4948	1216	44.17	6.50	3/25 1913	18.9	15.0	Dec. 1963	7.0	Dec. 1963	83	28	10	40	21	106	3	Year

(a) Years of record used.
T Trace, an amount too small to measure.
\+ Also on earlier dates, months, or years.

* Less than one half
** Accumulation below 65° for heating; above 65°, cooling. The former calculated from monthly mean temperature.

CLIMATE OF BLOOMINGTON, INDIANA

Bloomington, home of Indiana University, located in Monroe County in South Central Indiana, has an invigorating climate because of the frequent changes of the weather. Pleasant, cloudless days are interspersed with some rainy days throughout the year. Rainfall is usually adequate in all seasons favoring a diversified agriculture. In the summer, when moisture utilization is high, a dry month of below normal rainfall may affect lawns, pastures, and crops.

Weather changes every few days come from the passing of weather fronts and associated centers of low and high air pressure. In general, a high brings lower temperatures, lower humidity and sunny days. An approaching low brings increasing temperatures, increasing southerly wind, higher humidity, and commencement of rain or showers. This activity is greatest in the spring and least in late summer and early fall.

Precipitation is well distributed throughout the year. However, there is a tendency for spring and early summer rains to exceed fall and winter precipitation. The spring rains are very reliable insuring near maximum soil moisture going into summer when evaporation losses exceed rainfall and dry soils become more probable. A crop-destroying drought has never been experienced in this area. About one-third of the annual rainfall flows into streams and out of the area.

The probability in percent for daily precipitation to exceed 0.1 inch or 0.5 inch is as follows:

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
.1in	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
.5in	9	7	10	7	10	11	11	8	7	5	7	6	8

A weather study of the area indicates the probability for unusually heavy rains in just a few hours to be:

Frequency in 100 years	Rain in 1 hour	6 hours	12 hours
4	2.4	4.2	4.8
10	2.1	3.3	3.8
50	1.7	2.8	3.2

Snow occasionally hampers travel and clogs roads. Heaviest snow storms come with lows out of the southwest. As they swirl northeastward abundant moisture flows in from the Gulf of Mexico. A storm out of the northwest, with an inward flow of colder, drier air, leaves less snow. Some mid-winters are thus cold but snowfall is normal or less. The record monthly snowfall for January is 11 inches (1918), for February, 13 inches (1914), and for March, 26 inches (1906).

Relative humidity is not measured at this station but estimates are possible from the climatology of the area. Relative humidity varies on sunny summer days from a percent in the 40's or 50's, in the early afternoon, to the 90's about sunrise. Relative humidity rises and falls much as temperature does during a typical day but the highest percent usually occurs with the minimum temperature and the lowest percent with the maximum temperature. The cool dry air behind a cold front is next in importance in changing relative humidity downward.

Winds blow most frequently from the southwest, however, in one or two of the winter months, prevailing winds are northwest. Damaging winds have three sources. In the order of diminishing areal coverage but increasing intensity, they are: lows, thunderstorms, and tornadoes. Only 9 tornadoes have been reported in the County since 1916. Very few were of sufficient size to injure people or property. Thunderstorms, including incidences of only lightning and thunder, occur about 48 days of the year. Most of these occur in the spring and early summer. They are seldom so severe as to cause loss of life, property, or crops. Death dealing smog or fog is unknown.

Degree days, in the above table, provide a comparative number for calculating heating or cooling requirements between different places and different times for human comfort. Heating degree days, for a single day, are obtained by subtracting the mean temperature from 65°F. For cooling degree days, 65 is subtracted from the day's mean temperature and then accumulated for a total.

The growing season (defined here as the number of days between the last spring and first fall temperature of 32°F.) averages 182 days in length. The season is 200 days or more in 10% of the years, 190 days or more in 25% of the years, less than 160 days in 25% of the years, and less than 150 days in 10% of the years.

Many days of the year are nearly ideal in temperature. A few days, in the summer when temperatures exceed 90° or mornings below zero in winter, tend to obscure this fact. The fall season is considered by many as the best time of year for outdoor activities. Spring is also a favorite season but this season has more days of rain and thunderstorms.

Data in this summary was assembled by Lawrence Bennett, a student in Geology, Indiana University, with the guidance of Professor Robert Blakely.

August 1968

Lawrence A. Schaal
Weather Bureau State Climatologist
Purdue University, Agronomy Department
Lafayette, Indiana

Table 1. (Continued)

Average Temperature (°F)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept.	Oct	Nov	Dec	Ann'l
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Total Precipitation (Inches)

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Ann'l
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

STATION HISTORY

This study of local climate is possible because citizens of the community for many years generously donated a few minutes a day, seven days a week, reading and recording weather information from government instruments. The Columbus weather station has been located at the Columbus Sewage Plant since June 17, 1955. Earlier observers, dates of service, and direction of station from nearest post office are: John A. Perry, February 1, 1887 to September 22, 1913 and [illegible] Perry, October 1, 1913 to April 1, 1920, 1 mile south of Columbus; Mrs. J. Glenn Perry, April 1, 1920 to March 5, 1922, [illegible] miles north of post office; Charles S. Barnaby, May 29, 1922 to December 21, 1925; William [illegible] Barnaby, December 26, 1925 to March 25, 1929; Robert [illegible] Barnaby, March 26, 1929 to February 28, 1953, and Lynn A. Barnaby, March 1, 1953 to June 16, 1955, 0.4 mile north. All of these earlier locations reported an elevation above mean sea level of 612 feet.

EXTREMES AND DATES OF OCCURRENCE ([illegible])

Month	Highest Temperature		Lowest Temperature		Greatest Daily Precipitation		Greatest Monthly Snowfall	
Jan.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Feb.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Mar.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Apr.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
May	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	T	[illegible]
June	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
July	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
Aug.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
Sept.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
Oct.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Nov.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Dec	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

PROBABILITY OF LOW TEMPERATURES IN SPRING AND FALL

Minimum Temp.	Percent of occurrence after the date in spring					Percent of occurrence before the date in fall				
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

This table summarizes for a 30-year period the dates when low temperatures such as 32°F. last occurred in the spring and first occurred in the fall. The average date is given in the 50% column. The table shows that the last temperature of 32° or lower in the spring occurs after [illegible] in [illegible] of the years, and before [illegible] in the fall. Probabilities for other temperatures are indicated. Reference: "Dates of Freezing Temperatures--Spring and Fall in Indiana," by L.A. Schaal, J.E. Newman, and F.H. Emerson.

U. S. DEPARTMENT OF COMMERCE, WEATHER BUREAU
IN COOPERATION WITH: PURDUE AGRICULTURAL EXPERIMENT STATION
CLIMATOGRAPHY OF THE UNITED STATES NO. [illegible]

LATITUDE [illegible] N.
LONGITUDE [illegible] W.
ELEVATION (GROUND) [illegible] Ft.

CLIMATOLOGICAL SUMMARY

STATION: COLUMBUS, INDIANA

Table 2

MEANS AND EXTREMES FOR PERIOD [illegible]

Month	Temperature (°F) Means: Daily maximum	Daily minimum	Monthly	Extremes: Record highest	Year	Record lowest	Year	Mean degree days **	Precipitation Totals (Inches): Mean	Greatest daily	Year	Snow, Sleet: Mean	Maximum monthly	Year	Greatest daily	Year	Mean number of days: Precip. .10 inch or more	Temperatures Max. 90° and above	Max. 32° and below	Min. 32° and below	Min. 0° and below	Month
(a)	30	30		30		30		30	30	30		30	30		30		10	30	30	30	30	
Jan.	40.4	21.7	31.1	71	1943	-17	1936	1011	3.86	3.09	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Jan.
Feb.	43.6	23.5	33.6	72	1954+	-15	1951	950	2.83	2.29	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Feb.
Mar.	53.5	31.1	42.3	86	1939	-7	1960	722	4.05	3.08	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Mar.
Apr.	65.2	43.3	53.3	92	1937	20	1954+	348	3.83	3.46	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Apr.
May	76.0	51.0	63.5	98	1936	27	1947	130	4.28	4.23	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	May
June	86.7	60.6	73.7	103	1936+	41	1956+	23	4.13	3.07	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	June
July	88.6	63.7	76.2	111	1936	48	1947	0	3.42	3.36	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	July
Aug.	87.5	61.8	74.7	108	1936	40	1946	4	3.33	3.52	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Aug.
Sept.	81.3	53.5	67.4	103	1939	29	1942	78	2.99	3.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Sept.
Oct.	70.2	42.8	57.0	92	1951	17	1952	378	3.32	2.77	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Oct.
Nov.	53.9	32.1	43.1	85	1950	-2	1950	651	3.23	2.30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Nov.
Dec.	42.0	23.1	32.6	71	1956	-11	1963+	964	2.71	2.32	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Dec.
Year	65.6	42.2	53.9	111	July 1936	-17	Jan. 1936	5064	42.77	5.09	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Year

(a) Average length of record, years.
T Trace, an amount too small to measure.
** Base 65°F
+ Also on earlier dates, months, or years.
* Less than one half.

CLIMATE OF COLUMBUS, INDIANA

Columbus, located in Bartholomew County in Central Indiana, has an invigorating climate because of the frequent changes of the weather. Pleasant, cloudless days are interspersed with some rainy days throughout the year. [illegible]

Weather changes [illegible]

Precipitation [illegible]

[illegible]

Snowfall [illegible]

Relative humidity [illegible]

Winds [illegible]

Heating degree days [illegible]

The growing season [illegible]

[illegible]

Lawrence A. Schaal
Weather Bureau State Climatologist
Purdue University, Agronomy Department
Lafayette, Indiana

Table 2. (Continued)

Average Temperature (°F)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann'l
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Total Precipitation (Inches)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann'l
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 2. (Continued)

Average Temperature (°F)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann'l
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

STATION HISTORY

[illegible]

PROBABILITY OF LOW TEMPERATURES IN SPRING AND FALL

[illegible]

DAILY MINIMUM TEMPERATURE 0°F. OR LOWER

[illegible]

DAILY MAXIMUM TEMPERATURE 95°F. OR HIGHER

[illegible]

Total Precipitation (inches)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann'l
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

third of the county is still developing and is characterized by gently undulating to rolling land between stream valleys. A drainage map of the county is shown in Figure 2.

Brown County is divided into three watersheds which are separated by east-west orientated upland ridges. Each watershed contains a single, major east-west flowing stream. Bean Blossom Creek occupies the northern most valley, the North Fork of Salt Creek occupies the middle valley, and the Middle Fork of Salt Creek occupies the southern most valley. These valleys were deepened and widened by Illinoian glacial meltwater and partially filled by sediment derived from the ice in the form of lacustrine deposits and glacial-fluvial terraces. The streams which today occupy these valleys are termed 'underfit' by geologists because they are too small to have formed the broad valleys through which they now flow.

The drainage patterns in Brown County are strongly influenced by the depth to and composition of the underlying bedrock. The streams in the southwest corner of the county show a coarse textured, rectangular drainage pattern. Stream texture is related to stream density and refers to the degree of dissection in a given area (i.e., coarse-textured means relatively undissected while fine textured means well dissected). The pattern for the rest of the county is finer textured and the tributaries exhibit a slight north-south parallelism. This north-south alignment is more pronounced in the south flowing streams. The south flowing streams are considerably longer than the northern flowing

Figure 2. DRAINAGE MAP
BROWN COUNTY
INDIANA
PREPARED FROM
1939 AAA AERIAL PHOTOGRAPHS
BY
STATE HIGHWAY COMMISSION OF INDIANA
AT
PURDUE UNIVERSITY
1946

streams, presumably due to the southward dip of the rock strata and differential erosion. In the northern portion of the county the drainage pattern is dendritic showing less rock control and the texture or drainage density is fine.

Table 3 shows drainage density (D.D) for selected areas in Brown County. Relatively high drainage densities combined with high runoff coefficients associated with the steep bedrock areas result in potentially high peak flows during periods of prolonged or brief and heavy precipitation. Gaging station data shown in Tables 4, 5 and 6 indicate maximum discharge has varied by an order of magnitude or two over the normal discharge for any given stream.

There are no natural lakes in Brown County. Numerous erosion control dams form small lakes and ponds along steep sloped tributaries. Lakes Monroe and Lemon are reservoirs formed by the damming of the middle fork of Salt Creek and Bean Blossom Creek in Monroe County. Lakes Sweetwater, Cordry, and Yellow Wood are also artifically formed by earthen dams. A few man-made channels are required to supplement the natural drainage in the flood plains.

Physiography

Brown County lies entirely within the Norman Upland physiographic subsection of Indiana (6). The Norman Upland is part of the Interior Low Plateaus Province of North America (see Figure 3).

Table 3. Drainage Density of Selected Areas of Brown County (4).

STREAM AND LOCATION	QUAD.	SEC.	TWN.	RNG.	DA*	D.D**
Bear Creek at Mouth	Morgantown	32	10N	2E	7.71	6.9
Bean Blossom Creek above North Fork of Bean Blossom Creek	Morgantown	26	10N	2E	18.4	7.5
Clay Lick Creek at Mouth	Nashville	20	9N	3E	5.27	8.5
Gravel Creek at Mouth	Story	31	8N	3E	4.97	5.8
Hamilton Creek at Mouth	Story	33	8N	3E	14.1	7.7
Jackson Creek at Mouth	Belmont	31	9N	2E	7.72	6.0
Lick Creek at Mouth	Morgantown	34	10N	2E	6.46	7.4
Little Blue Creek at Mouth	Elkinsville	36	8N	2E	5.24	6.0
Lower Schooner Creek at Mouth	Belmont	5	8N	2E	12.0	5.6
Owl Creek at Mouth	Belmont	27	9N	2E	5.62	6.4

* DA - Drainage Area, in square miles
**DD - Drainage Density (number of streams per square mile)

Table 4. Stream Flow Data; Bear Creek (36 and 37).

WABASH RIVER BASIN

03355000 Bear Creek near Trevlac, Ind.

LOCATION.--Lat 39°16'40", long 86°20'45", in NE 1/4 NE 1/4 sec.30, T.10 N., R.2 E., Brown County, on left bank 15 ft (5 m) west of Bear Creek Road, 100 ft (30 m) upstream from Slippery Elm Shoot Road ford, 1.1 miles (1.8 km) northwest of Trevlac, and 1.3 miles (2.1 km) upstream from mouth.

DRAINAGE AREA.--6.94 sq mi (17.97 sq km).

PERIOD OF RECORD.--May 1952 to September 1973 (discontinued as a continuous-record station; converted to a crest-stage and low-flow partial-record station).

GAGE.--Water-stage recorder and concrete control. Altitude of gage is 640 ft (195 m), from topographic map.

AVERAGE DISCHARGE.--21 years, 6.69 cfs (0.189 cu m/s), 13.09 in/yr (332 mm/yr).

EXTREMES.--Current year: Maximum discharge, 379 cfs (10.9 cu m/s) Nov. 13, gage height, 4.37 ft (1.??? m); minimum daily, 0.05 cfs (0.001 cu m/s) Sept. 7.

Period of record: Maximum discharge, 1,830 cfs (51.8 cu m/s) June 12, 1957, gage height, 7.62 ft (2.323 m), from rating curve extended above 290 cfs (8.21 cu m/s) on basis of slope-area measurement of peak flow at gage height, 6.43 ft (1.960 m); no flow at times most years.

REMARKS.--Records good except for period of no gage-height record, which is fair.

LOWEST MEAN DISCHARGE, IN CFS, AND RANKING, FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS IN YEAR ENDING MARCH 31

YEAR	1	3	7	14	30	60	90	120	183	ANNUAL
1954	0.00 1	0.00 1	0.00 1	0.00 1	0.00 1	0.00 1	0.00 1	0.00 1	0.10 5	3.30 1
1955	0.00 2	0.00 2	0.00 2	0.00 2	0.00 2	0.00 2	0.02 3	0.02 2	0.09 1	4.00 6
1956	0.00 3	0.00 3	0.00 3	0.00 3	0.00 3	0.01 4	0.17 13	0.40 16	2.20 16	7.60 14
1957	0.00 4	0.00 4	0.00 4	0.00 4	0.00 4	0.02 7	0.27 16	0.25 10	1.20 12	5.00 8
1958	0.00 5	0.00 5	0.00 5	0.00 5	0.02 14	0.05 12	0.10 9	0.30 12	2.70 18	9.90 18
1959	0.00 6	0.23 20	0.27 20	0.83 20	1.90 20	1.00 20	2.20 20	2.40 20	4.40 20	11.40 20
1960	0.00 7	0.00 6	0.00 6	0.00 6	0.00 5	0.14 16	0.19 14	0.35 14	1.20 13	6.60 12
1961	0.00 8	0.00 7	0.00 7	0.00 7	0.01 11	0.03 8	0.04 6	0.08 6	0.13 3	6.00 9
1962	0.00 9	0.00 8	0.00 8	0.00 8	0.01 12	0.05 9	0.06 7	0.08 7	0.50 7	8.00 15
1963	0.00 10	0.00 9	0.04 18	0.06 18	0.17 19	0.35 19	0.50 19	0.58 17	0.94 10	4.50 4
1964	0.00 11	0.00 10	0.00 9	0.00 9	0.00 6	0.01 5	0.02 4	0.03 3	0.16 4	3.30 2
1965	0.00 12	0.00 11	0.00 10	0.00 10	0.00 7	0.00 3	0.00 2	0.04 4	0.10 2	4.00 5
1966	0.00 13	0.00 12	0.00 11	0.00 11	0.00 8	0.05 10	0.20 17	0.39 15	1.50 15	5.10 7
1967	0.00 14	0.00 13	0.00 12	0.00 12	0.01 9	0.05 11	0.08 8	0.30 13	1.10 11	8.80 16
1968	0.00 15	0.00 14	0.00 13	0.00 13	0.01 10	0.02 6	0.04 5	0.06 5	0.21 6	6.30 10
1969	0.00 16	0.00 15	0.00 14	0.04 17	0.10 17	0.14 17	0.15 12	0.95 18	3.00 19	10.70 19
1970	0.04 20	0.04 19	0.07 19	0.13 19	0.15 18	0.21 18	0.44 18	2.40 19	2.60 17	6.60 11
1971	0.00 17	0.00 16	0.00 15	0.03 15	0.07 15	0.09 14	0.14 10	0.17 8	0.70 9	7.20 13
1972	0.00 18	0.00 17	0.01 17	0.03 16	0.09 16	0.14 15	0.20 15	0.26 11	0.64 8	3.40 3
1973	0.00 19	0.00 18	0.00 16	0.00 14	0.02 13	0.06 13	0.14 11	0.21 9	1.40 14	9.90 17

HIGHEST MEAN DISCHARGE, IN CFS, AND RANKING, FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS IN YEAR ENDING SEPTEMBER 30

YEAR	1	3	7	15	30	60	90	120	183	ANNUAL
1953	103.0 20	55.0 20	45.1 18	25.7 20	17.5 20	14.7 19	14.4 18	11.7 17	8.6 18	4.4 18
1954	60.0 21	31.7 21	17.8 21	16.2 21	14.4 21	10.2 21	7.6 21	6.7 21	4.7 21	2.4 21
1955	141.0 16	77.7 17	44.0 19	33.2 16	21.9 19	20.7 13	16.7 13	15.2 10	12.0 10	6.2 12
1956	223.0 8	109.0 10	57.9 15	30.3 18	29.2 13	21.2 11	18.7 7	17.6 7	13.3 8	8.1 7
1957	230.0 6	151.0 5	88.7 4	52.5 6	35.2 5	27.9 3	22.9 2	18.3 6	15.1 6	8.1 8
1958	144.0 15	135.0 7	71.6 8	50.7 7	32.4 6	20.9 12	17.5 11	15.3 9	12.8 9	9.6 2
1959	314.0 4	133.0 8	64.4 13	36.7 14	32.1 9	25.9 5	21.1 5	29.3 2	16.1 3	8.7 4
1960	381.0 2	146.0 6	56.6 9	35.1 15	22.5 18	14.3 20	12.6 20	11.7 18	11.7 11	7.0 10
1961	402.0 1	254.0 1	138.0 1	74.7 1	49.6 1	33.9 1	29.5 1	24.1 1	16.0 4	8.1 9
1962	138.0 18	69.7 18	39.1 20	27.5 19	25.1 17	16.1 18	14.2 19	11.9 16	9.6 17	5.3 17
1963	150.0 13	103.0 11	54.3 16	42.3 10	32.0 10	19.0 14	14.0 15	11.5 19	8.1 19	4.3 19
1964	230.0 7	120.0 9	65.0 10	30.0 17	26.2 15	21.5 9	14.7 16	11.3 20	7.5 20	3.8 20
1965	132.0 19	89.0 15	74.6 7	38.2 12	29.7 12	21.7 8	18.5 8	14.5 11	9.7 16	5.5 14
1966	178.0 10	92.7 14	62.1 14	42.7 9	28.0 14	16.3 17	14.5 17	13.0 15	10.3 15	5.4 15
1967	173.0 11	152.0 4	91.9 3	54.2 5	30.4 11	18.9 15	17.8 9	16.3 8	16.2 2	8.6 5
1968	366.0 3	225.0 2	124.0 2	65.6 2	38.4 3	26.5 4	21.2 4	20.1 3	15.9 5	9.3 3
1969	238.0 5	166.0 3	86.0 5	63.0 3	38.0 2	25.7 6	18.8 6	18.6 4	13.7 7	8.1 6
1970	140.0 17	66.3 19	51.7 17	33.1 17	25.2 16	18.6 16	17.2 12	14.3 12	11.5 12	6.0 13
1971	149.0 14	81.7 16	64.9 12	46.5 8	32.3 8	21.4 10	16.6 14.	13.7 14	11.4 13	6.2 11
1972	191.0 9	99.7 13	83.6 6	57.5 4	35.0 4	23.0 7	17.5 10	13.9 13	10.3 14	5.4 16
1973	168.0 12	102.0 12	65.7 11	40.2 11	32.4 7	28.3 2	21.4 3	18.6 *5	17.0 1	9.9 1

ANNUAL PEAKS

1953	252
1954	254
1955	478
1956	1540
1957	1430
1958	948
1959	1100
1960	1570
1961	1400
1962	274
1963	412
1964	446
1965	412
1966	494
1967	412
1968	1440
1969	436
1970	314
1971	270
1972	544
1973	379

Table 5. Stream Flow Data; North Fork of Salt Creek (36 and 37).

WABASH RIVER BASIN

03371650 North Fork Salt Creek at Nashville, Ind.

LOCATION.--Lat 39°12'24", long 86°14'[illegible]", in NE 1/4 SW 1/4 sec.[illegible], T.9 N., R.3 E., Brown County, on right bank [illegible] ft ([illegible] m) downstream from bridge on State Highway 46, [illegible] ft ([illegible] m) downstream from Greasy Creek, and [illegible] mile ([illegible] km) south of center of Nashville.

DRAINAGE AREA.--[illegible] sq mi ([illegible] sq km).

PERIOD OF RECORD.--July 1962 to current year.

GAGE.--Water-stage recorder. Datum of gage is [illegible] ft ([illegible] m) above mean sea level. Prior to Sept. [illegible], 1964, nonrecording gage at site [illegible] ft ([illegible] m) upstream at same datum.

AVERAGE DISCHARGE.--11 years, [illegible] cfs ([illegible] cu m/s), [illegible] in/yr ([illegible] mm/yr).

EXTREMES.--Current year: Maximum discharge, [illegible] cfs ([illegible] cu m/s) Mar. [illegible], gage height, [illegible] ft ([illegible] m); minimum daily, [illegible] cfs ([illegible] cu m/s) Sept. [illegible].
Period of record: Maximum discharge, [illegible] cfs ([illegible] cu m/s) Mar. [illegible], 1963; maximum gage height, [illegible] ft ([illegible] m) May [illegible], 19[illegible]; no flow at times most years.

REMARKS.--Records good.

LOWEST MEAN DISCHARGE, IN CFS, AND RANKING, FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS IN YEAR ENDING MARCH 31

YEAR	1	3	7	14	30	60	90	120	183	ANNUAL
1964	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1965	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1966	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1967	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1968	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1969	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1970	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1971	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1972	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1973	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

HIGHEST MEAN DISCHARGE, IN CFS, AND RANKING, FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS IN YEAR ENDING SEPTEMBER 30

YEAR	1	3	7	15	30	60	90	120	183	ANNUAL
1963	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1964	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1965	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1966	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1967	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1968	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1969	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1970	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1971	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1972	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1973	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

ANNUAL PEAKS

1962	[illegible]
1963	[illegible]
1964	[illegible]
1965	[illegible]
1966	[illegible]
1967	[illegible]
1968	[illegible]
1969	[illegible]
1970	[illegible]
1971	[illegible]
1972	[illegible]
1973	[illegible]

Table 5. Stream Flow Data; North Fork of Salt Creek (36 and 37).

WABASH RIVER BASIN

03371650 North Fork Salt Creek at Nashville, Ind.

LOCATION.--Lat 39°12'06", long 86°14'51", in NW 1/4 SW 1/4 sec.19, T.9 N., R.3 E., Brown County, on right bank 90 ft (27 m) downstream from bridge on State Highway 46, 800 ft (244 m) downstream from Greasy Creek, and 0.4 mile (0.6 km) south of center of Nashville.

DRAINAGE AREA.--76.1 sq mi (197.1 sq km).

PERIOD OF RECORD.--July 1962 to current year.

GAGE.--Water-stage recorder. Datum of gage is 579.58 ft (176.656 m) above mean sea level. Prior to Sept. 16, 1964, nonrecording gage at site 90 ft (27 m) upstream at same datum.

AVERAGE DISCHARGE.--11 years, 75.9 cfs (2.149 cu m/s), 13.54 in/yr (344 mm/yr).

EXTREMES.--Current year: Maximum discharge, 3,140 cfs (88.9 cu m/s) Mar. 11, gage height, 11.63 ft (3.545 m); minimum daily, 1.9 cfs (0.054 cu m/s) Sept. 1, 6, 7.

Period of record: Maximum discharge, 7,500 cfs (212 cu m/s) Mar. 4, 1963; maximum gage height, 16.00 ft (4.877 m) May 24, 1965; no flow at times most years.

REMARKS.--Records good.

LOWEST MEAN DISCHARGE, IN CFS, AND RANKING, FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS IN YEAR ENDING MARCH 31

YEAR	1	3	7	14	30	60	90	120	183	ANNUAL
1964	0.00 1	0.00 1	0.00 1	0.00 1	0.00 1	0.00 1	0.10 2	0.30 2	1.40 2	48.30 2
1965	0.00 2	0.00 2	0.00 2	0.00 2	0.00 2	0.00 2	0.00 1	0.00 1	1.10 1	52.40 4
1966	0.80 8	0.90 8	1.00 8	1.30 8	2.40 9	5.00 9	6.50 9	7.10 7	12.90 6	51.60 3
1967	0.00 3	0.10 5	0.10 5	0.20 5	0.30 5	1.90 6	5.20 8	7.50 8	15.80 7	90.30 8
1968	0.00 4	0.00 3	0.00 3	0.00 3	0.00 3	0.20 3	0.50 3	1.20 3	3.40 3	70.10 5
1969	0.30 6	0.30 6	0.30 6	0.40 6	0.50 6	1.00 5	1.90 5	7.60 9	30.70 9	113.00 9
1970	2.90 10	2.90 10	3.10 10	3.60 10	4.40 10	6.90 10	9.10 10	32.00 10	37.80 10	85.80 7
1971	0.90 9	1.00 9	1.10 9	1.30 9	1.70 8	2.40 7	3.10 6	3.50 5	9.60 5	80.70 6
1972	0.40 7	0.50 7	0.60 7	0.70 7	1.20 7	2.40 8	3.50 7	3.50 6	5.80 4	37.70 1
1973	0.00 5	0.00 4	0.00 4	0.10 4	0.10 4	0.50 4	1.60 4	3.20 4	20.10 8	113.00 10

HIGHEST MEAN DISCHARGE, IN CFS, AND RANKING, FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS IN YEAR ENDING SEPTEMBER 30

YEAR	1	3	7	15	30	60	90	120	183	ANNUAL
1963	2710.0 5	1720.0 5	863.0 5	757.0 1	516.0 1	301.0 3	210.0 5	142.0 7	110.0 8	56.7 9
1964	5030.0 1	2930.0 1	1400.0 1	742.0 2	486.0 2	341.0 1	233.0 2	178.0 5	119.0 7	59.6 8
1965	2300.0 7	1140.0 7	594.0 10	302.0 11	254.0 10	197.0 10	191.0 8	152.0 9	102.0 10	55.3 10
1966	1380.0 11	738.0 11	533.0 11	324.0 10	253.0 11	154.0 11	133.0 11	124.0 11	94.8 11	52.1 11
1967	1850.0 10	1740.0 4	1080.0 3	582.0 6	333.0 7	236.0 7	208.0 6	181.0 4	180.0 2	97.2 2
1968	4570.0 2	2250.0 2	1280.0 2	646.0 4	420.0 3	275.0 4	225.0 3	200.0 3	161.0 3	94.8 4
1969	3240.0 3	1750.0 3	927.0 4	682.0 3	408.0 4	266.0 5	210.0 4	215.0 2	161.0 4	96.6 3
1970	2670.0 6	1140.0 8	642.0 9	403.0 9	304.0 9	217.0 8	190.0 9	169.0 6	141.0 5	75.8 5
1971	2050.0 8	1050.0 9	752.0 7	462.0 8	307.0 8	207.0 9	164.0 10	138.0 10	109.0 9	60.0 7
1972	2910.0 4	1220.0 6	772.0 6	590.0 5	366.0 6	251.0 6	204.0 7	161.0 8	124.0 6	64.3 6
1973	1870.0 9	1020.0 10	705.0 8	506.0 7	384.0 5	337.0 2	256.0 1	221.0 1	197.0 1	122.0 1

ANNUAL PEAKS

1962	4600
1963	7500
1964	7130
1965	4220
1966	2620
1967	3820
1968	7200
1969	4950
1970	4820
1971	3750
1972	5140
1973	3140

Table 6. Stream Flow Data; Bean Blossom Creek (36 and 37).

WABASH RIVER BASIN

03354500 Beanblossom Creek at Beanblossom, Ind.

LOCATION.--Lat 39°15'45", long 86°14'55", in SW 1/4 NW 1/4 sec.31, T.10 N., R.3 E., Brown County, on right bank 15 ft (5 m) downstream from bridge on State Highway 135, 0.3 mile (0.5 km) south of Beanblossom, and 2.5 miles (4.0 km) upstream from North Fork Beanblossom Creek.

DRAINAGE AREA.--14.6 sq mi (37.8 sq km).

PERIOD OF RECORD.--October 1951 to current year. Prior to October 1965, published as Bean Blossom Creek at Bean Blossom.

GAGE.--Water-stage recorder. Datum of gage is 673.65 ft (205.329 m) above mean sea level.

AVERAGE DISCHARGE.--22 years, 15.7 cfs (0.445 cu m/s), 14.60 in/yr (371 mm/yr).

EXTREMES.--Current year: Maximum discharge, 952 cfs (27.0 m) July 24, gage height, 6.49 ft (1.978 m); minimum daily, 0.05 cfs (0.001 cu m/s) Oct. 10.

Period of record: Maximum discharge, 8,140 cfs (231 cu m/s) June 23, 1960, gage height, 11.78 ft (3.591 m), from curve extended above 2,000 cfs (56.6 cu m/s) on basis of contracted-opening measurement; no flow for many days in most years.

REMARKS.--Records fair.

LOWEST MEAN DISCHARGE, IN CFS, AND RANKING, FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS IN YEAR ENDING MARCH 31

YEAR	1	3	7	14	30	60	90	120	183	ANNUAL
1953	[illegible] 1	[illegible] 1	[illegible] 1	[illegible] 1	[illegible] 1	0.02 9	0.06 6	0.05 3	0.66 8	11.90 9
1954	0.03 2	[illegible] 2	[illegible] 2	[illegible] 2	[illegible] 2	0.00 1	0.00 1	0.07 5	0.20 4	5.13 1
1955	[illegible] 3	[illegible] 3	[illegible] 3	[illegible] 3	[illegible] 3	0.01 7	0.03 5	0.06 4	0.10 1	9.00 4
1956	[illegible] 4	[illegible] 4	[illegible] 4	[illegible] 4	0.00 4	0.01 8	0.43 16	0.92 16	2.05 12	11.80 6
1957	[illegible] 5	[illegible] 5	[illegible] 5	[illegible] 5	[illegible] 5	0.09 10	0.49 17	0.44 12	2.74 13	13.30 12
1958	[illegible] 6	[illegible] 6	[illegible] 6	0.00 6	0.04 13	0.14 12	0.25 10	0.65 14	6.93 20	24.90 20
1959	[illegible] 21	0.83 21	1.06 21	1.48 21	[illegible] 21	3.65 21	4.30 21	6.66 21	11.00 21	28.90 21
1960	[illegible] 7	[illegible] 7	[illegible] 7	[illegible] 14	[illegible] 14	1.43 20	3.33 20	3.83 19	5.23 17	12.60 10
1961	[illegible] 8	[illegible] 6	[illegible] 8	[illegible] 7	[illegible] 6	0.00 2	0.09 7	0.26 9	0.48 6	13.50 11
1962	[illegible] 9	[illegible] 9	[illegible] 9	[illegible] 8	0.00 7	0.00 3	0.02 4	0.11 6	0.47 5	18.30 16
1963	[illegible] 16	[illegible] 16	[illegible] 16	[illegible] 17	0.10 16	0.24 15	0.40 15	0.99 13	1.17 9	11.70 8
1964	[illegible] 11	[illegible] 11	[illegible] 12	[illegible] 9	[illegible] 8	0.00 4	0.00 2	0.01 2	0.18 3	9.43 5
1965	[illegible] 12	[illegible] 12	[illegible] 11	[illegible] 10	[illegible] 9	0.03 5	0.00 3	0.00 1	0.10 2	8.01 3
1966	[illegible] 13	[illegible]	[illegible] 12	[illegible] 15	0.28 18	0.78 18	0.74 18	1.04 17	3.99 16	11.60 7
1967	[illegible] 14	[illegible] 14	[illegible] 13	[illegible] 11	0.01 12	0.25 16	0.36 13	0.74 15	3.30 14	20.30 17
1968	[illegible] 15	[illegible] 15	[illegible] 14	[illegible] 12	[illegible] 10	0.01 6	0.11 8	0.16 7	0.56 7	15.90 14
1969	[illegible] 19	[illegible] 19	0.15 19	0.26 19	0.28 19	0.30 17	0.37 14	2.91 18	6.47 18	24.40 19
1970	[illegible] 20	0.25 20	[illegible] 20	[illegible] 20	0.74 20	0.86 19	1.47 19	6.47 20	6.74 19	16.70 15
1971	[illegible]	[illegible]	[illegible] 17	[illegible] 16	0.67 15	0.22 14	0.26 11	0.36 10	1.22 10	14.90 13
1972	[illegible] 18	[illegible] 18	[illegible] 18	[illegible] 18	0.13 17	0.21 13	0.31 12	0.40 11	1.52 11	6.53 2
1973	[illegible] 17	[illegible] 17	[illegible] 15	[illegible] 13	[illegible] 11	0.06 11	0.20 9	0.26 8	3.47 15	22.40 18

HIGHEST MEAN DISCHARGE, IN CFS, AND RANKING, FOR THE FOLLOWING NUMBER OF CONSECUTIVE DAYS IN YEAR ENDING SEPTEMBER 30

YEAR	1	3	7	15	30	60	90	120	183	ANNUAL
1952	584.0 8	342.0 9	247.0 6	134.0 6	122.0 1	91.6 1	74.5 1	68.5 1	56.7 1	29.9 1
1953	262.0 20	138.0 20	66.5 21	44.2 21	39.2 21	30.1 21	28.0 20	22.9 20	17.6 21	9.0 21
1954	74.0 22	61.0 22	37.8 22	29.2 22	21.4 22	14.4 22	11.7 22	10.2 22	7.7 22	3.9 22
1955	190.0 21	121.0 21	74.9 20	50.3 20	42.5 20	35.4 16	28.5 19	25.9 16	18.5 19	9.6 19
1956	330.0 18	196.0 18	99.9 18	55.5 19	53.1 15	38.0 14	39.2 13	32.6 10	27.2 10	15.7 10
1957	509.0 11	357.0 8	263.0 4	137.0 5	74.3 11	69.3 3	51.5 4	43.6 5	35.9 5	19.4 7
1958	346.0 17	336.0 10	176.0 12	123.0 10	79.8 8	52.9 9	46.8 7	40.8 7	35.5 6	26.0 2
1959	1150.0 2	428.0 6	200.0 8	149.0 11	92.6 3	63.5 5	48.9 5	40.1 9	31.6 9	18.7 8
1960	1220.0 1	460.0 3	205.0 7	99.1 14	54.7 14	31.2 19	24.4 21	22.9 21	23.4 13	14.7 11
1961	1080.0 5	652.0 1	329.0 1	173.0 1	113.0 2	74.9 2	47.0 2	52.3 2	34.6 7	17.5 9
1962	288.0 19	164.0 19	92.0 19	60.6 18	49.4 17	33.5 18	30.6 17	25.0 19	21.3 15	11.9 15
1963	545.0 9	297.0 12	147.0 14	124.0 9	16.2 5	52.5 10	36.8 11	30.5 12	20.8 16	10.8 18
1964	1110.0 4	460.0 4	230.0 5	129.0 7	71.8 12	51.1 11	35.1 14	27.0 16	17.9 20	9.0 20
1965	405.0 16	229.0 14	117.0 16	68.8 17	48.4 18	36.8 15	35.5 12	26.2 15	18.9 18	11.0 16
1966	465.0 13	215.0 15	121.0 15	76.1 15	52.4 16	30.3 20	29.2 18	26.0 17	20.6 17	11.0 17
1967	503.0 12	434.0 5	247.0 3	150.0 2	83.8 7	53.1 8	45.9 8	40.2 8	41.8 2	22.6 4
1968	1130.0 3	577.0 2	360.0 2	149.0 3	89.5 6	60.0 6	48.0 6	46.1 3	36.2 4	20.7 6
1969	669.0 7	400.0 7	198.0 9	145.0 4	83.3 6	56.8 7	43.8 9	42.7 6	32.6 8	21.1 5
1970	371.0 10	211.0 17	116.0 17	69.6 16	46.3 19	34.6 17	32.1 16	28.4 14	23.9 11	13.0 12
1971	460.0 14	212.0 16	163.0 13	99.0 13	65.3 13	43.8 13	34.5 15	28.5 13	22.3 14	12.0 14
1972	770.0 6	304.0 11	188.0 10	129.0 8	78.0 9	48.6 12	39.3 10	30.9 11	23.7 12	12.2 13
1973	418.0 15	252.0 13	185.0 11	106.0 12	74.9 10	68.8 4	52.3 3	44.7 4	40.2 3	24.5 3

ANNUAL PEAKS

1952	5840
1953	790
1954	335
1955	780
1956	2250
1957	2140
1958	2360
1959	2600
1960	8140
1961	3000
1962	1270
1963	1540
1964	2140
1965	1300
1966	1340
1967	1940
1968	3390
1969	2270
1970	1740
1971	1130
1972	2480
1973	952

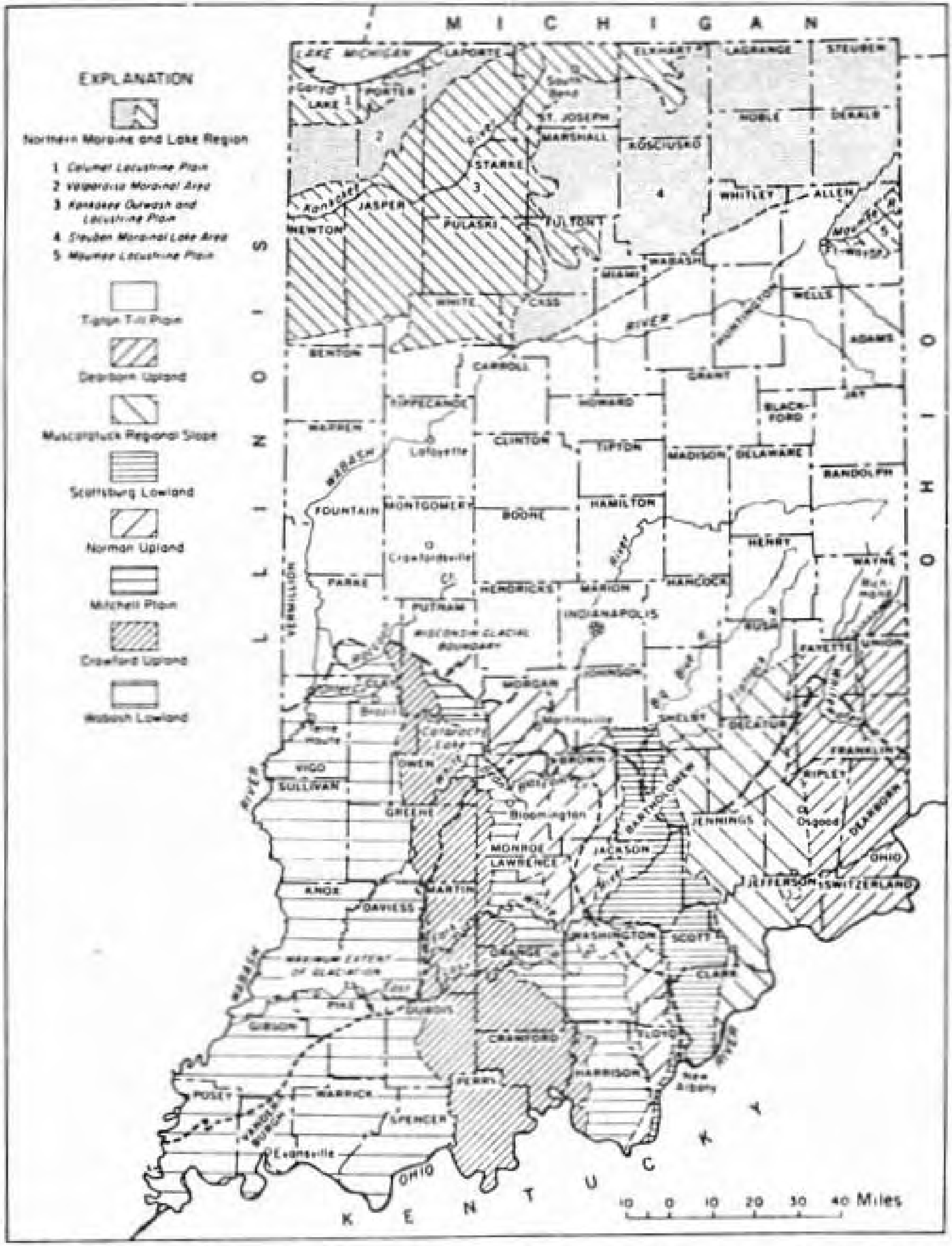

Figure 3. Map of Indiana showing physiographic units and glacial boundaries (4), modified.

General Geology

The surficial geology of Brown County consists of bedrock of Paleozic age and unconsolidated materials of the Quarternary period (6). Surface bedrock lithology is interbedded sandstone - shales of the lower Mississippian period which are predominantly overlain by residual soils. Most of the unconsolidated glacial till, the fluvial and lacustrine terraces and loess blanket are of Illinoian and Wisconsinan age while the flood plain deposits and some small fluvial terraces are of recent time.

Bedrock Geology

The surface bedrock is part of the Mississippian Borden group Figure 4). The Borden group is divided into the following formations from older (lower) to younger (upper); the New Providence shale, the Carwood, the Locust Point, the Edwardsville, and Floyds Knob. The New Providence formation, is a soft, greenish clay-shale and is 120-150 feet thick. The overlying members (the Carwood, the Locust Point, etc.) are interbedded sandstone - shales, wherein the shale units predominate both in number and thickness. The shales are soft, gray-green clay-shales. The sandstone units are rarely more than one foot thick and occur more frequently in the younger, upper members. The sandstones are composed of a dirty (minor percentages of silt and clay) fine sand. A representative stratigraphic column for Brown County is given on Figure 5.

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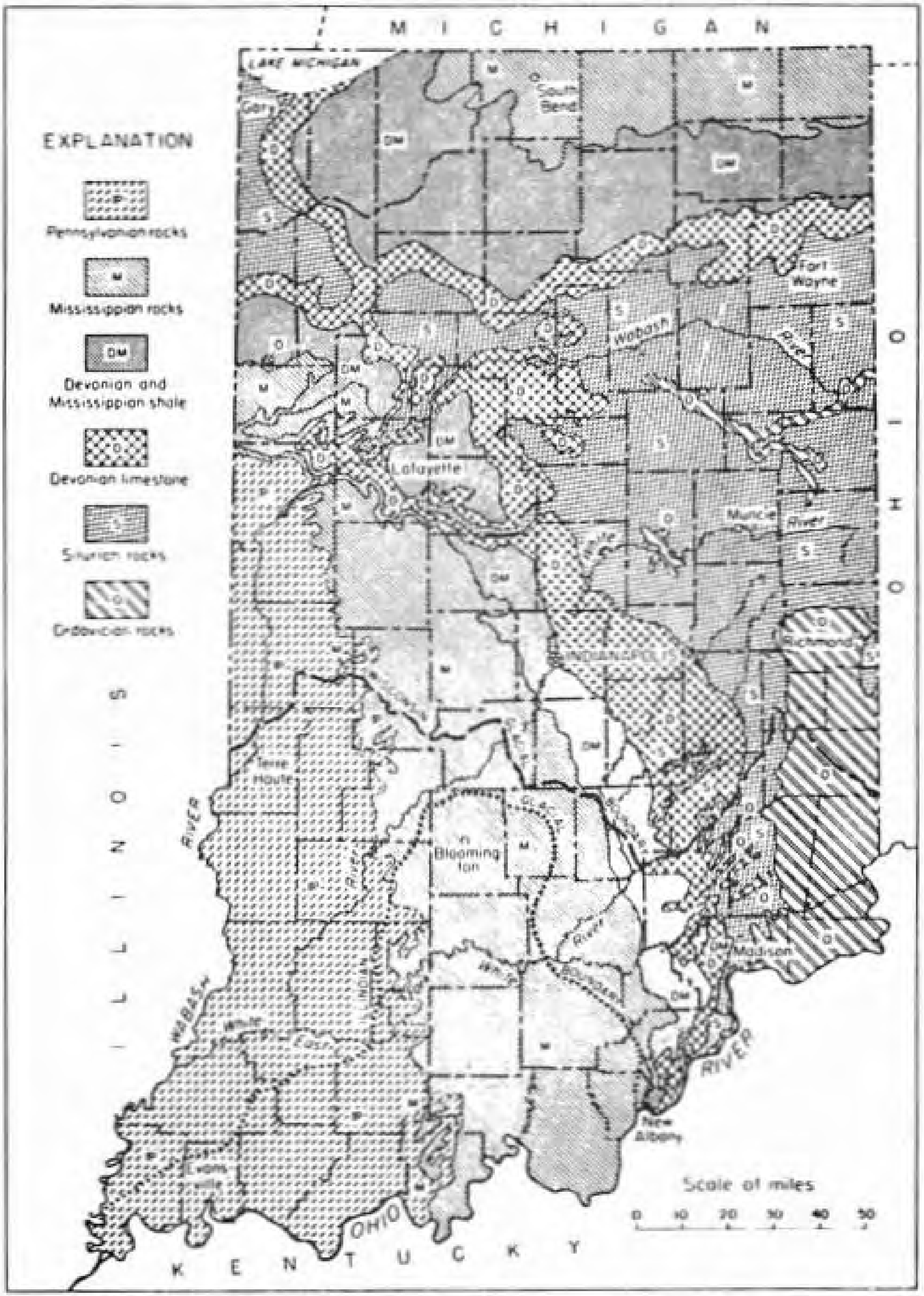


Figure 4. Generalized bedrock geology map of Indiana (45).

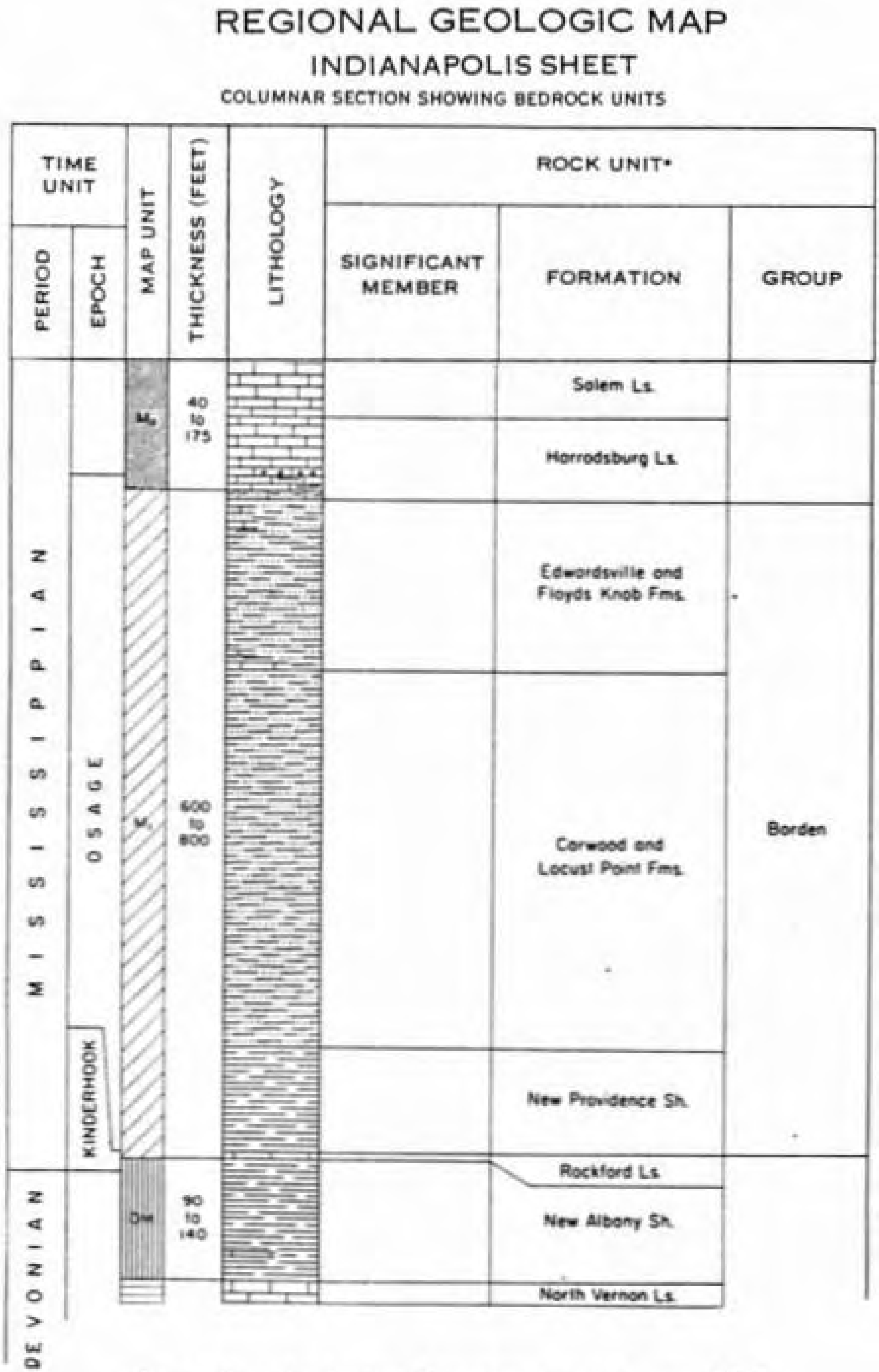


Figure 5. Geologic Column for Brown County (46).

The Borden group is structurally part of a gently dipping, dissected peneplain (2). The regional dip is less than two degrees toward the southwest (6). Folding and significant faulting are unknown in the county. Structural features, including jointing and minor shear zones, are presumably associated with the tectonic forces which formed the Cincinati Arch to the northeast and caused the uplift of the sandstone - shale plain. Local jointing is widely (3-10 feet) spaced and the rock mass is termed 'moderately jointed' by engineering geologists.

The exposed bedrock surfaces exhibit a benched morphology due to the contrast in weathering and erosion rates between the shale and sandstone units. The shale units weather more quickly forming a soft, plastic clay, leaving the more resistant sandstone units as benches or cantilevers which are easily identified in the field. Slope angles range from 35° to nearly vertical. The greater the frequency of sandstone units the steeper the slope and the shallower the depth to bedrock (e.g., the thinner the soil cover).

Glacial Geology

The ice of the Illinoian glaciation advanced into northern and southeastern Brown County in the form of contemporaneous ice lobes from the main ice sheet approximately 27,000-36,000 years ago (6). The northern lobe entered the county along a topographic break in the northern most east - west bedrock upland ridge (see Topography section). The ice advanced southward to Bean Blossom Creek, scouring and widening the bedrock valleys, modifying adjacent slopes and depositing glacial drift in the form of ground moraine. To the southeast, the ice sheet overrode portions of the Knobstone escarpment modifying the local relief and depositing a thin blanket of ground moraine.

Preglacial bedrock morphology largely dictated drift deposition and subsequent thickness (7). The ice sheets filled the valleys and only thinly covered some of the upland surfaces. The thickest drift (up to 37 feet) was deposited in the northern portion of the county northwest of Goshen Church and along portions of the valley of the west fork of Bean Blossom Creek (see Figure 6). Drift deposited in the southeast part of the county was relatively thin (two to six feet).

During the recessional period of the Illinoian glaciation, ice blocked the White River in Monore County resulting in the formation of meltwater lakes in the valleys of Bean Blossom Creek and the forks of Salt Creek (6,8). Clay, silt, sand, and gravel, primarily glacially derived, were deposited in the lakes forming lacustrine and valley - fill terrace deposits. Breeching of the ice dam resulted in a deluge of meltwater which rushed from the temporary glacial lakes. The meltwaters of the receding glacier scoured the valley walls forming bedrock benches, depositing thin layers of sand and gravel on some of them. The meltwater dissected the lake deposits leaving mainly bedrock defended lacustrine terraces.

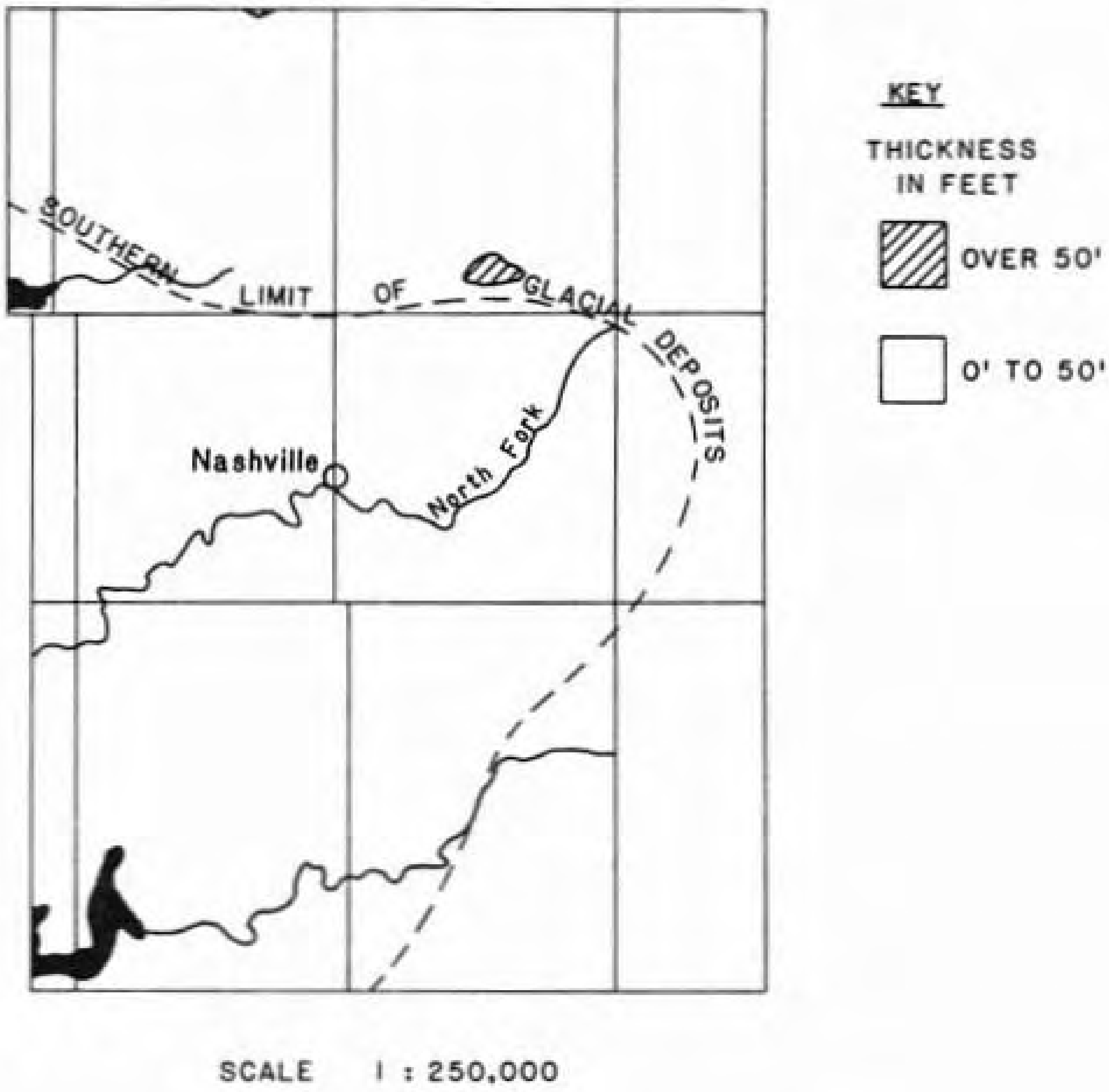


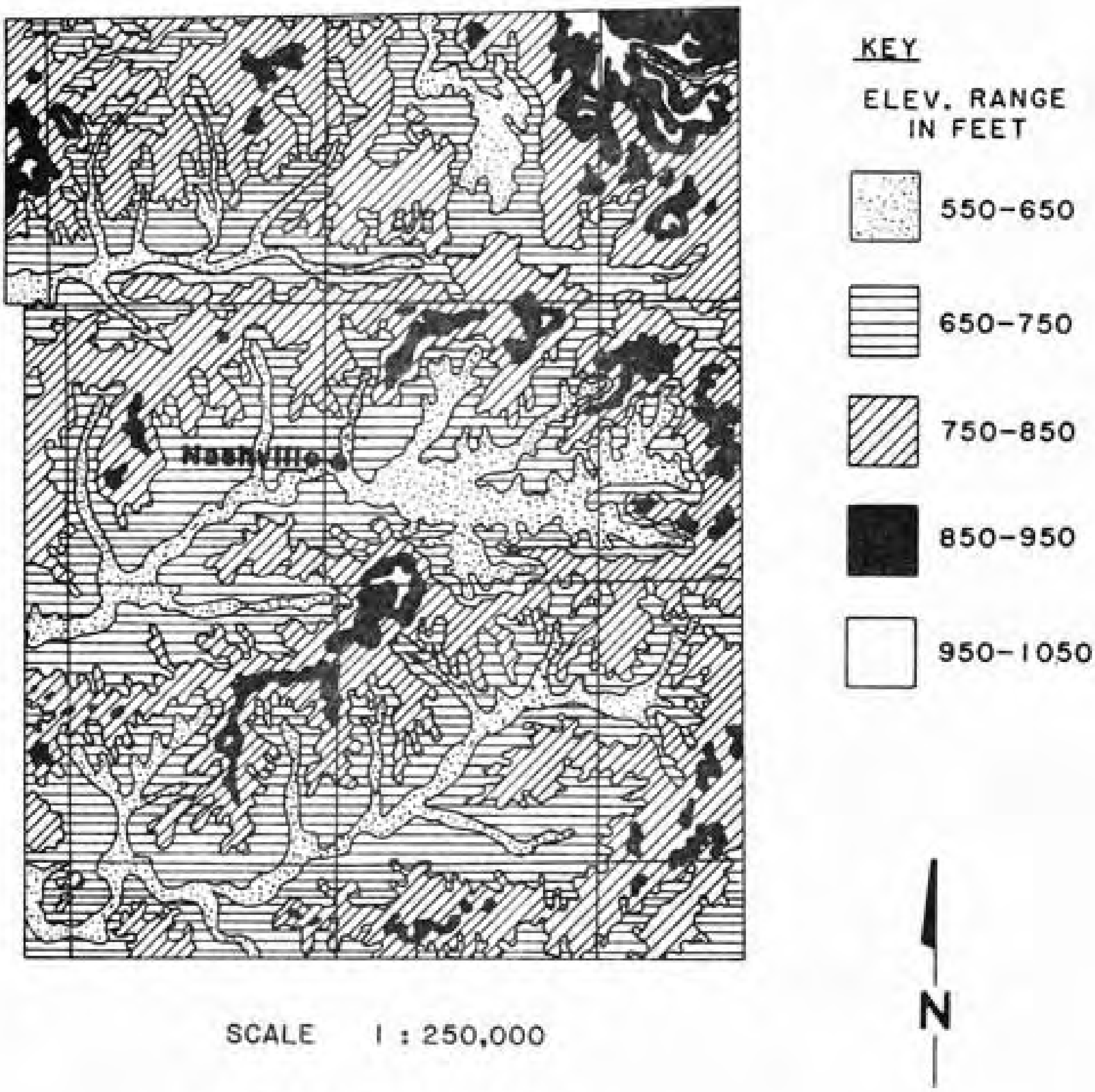
FIG. 6. MAP OF BROWN COUNTY SHOWING THICKNESS OF UNCONSOLIDATED DEPOSITS (42).

The Wisconsinan glaciation followed the Illinoian from about 25,000 to 12,000 years ago. The Wisconsinan ice covered a small area in the extreme northeastern corner of Brown County, depositing ground moraine but had little affect on the morphology of the area. Little erosion or deposition occurred in Brown County as a result of the Wisconsinan meltwater.

Topography

Brown County is characterized by rugged, hilly terrain in the bedrock areas and terrain of moderate relief in the glaciated areas to the north and southeast. The county exhibits considerable local relief, particularly in bedrock areas. The lowest elevation (560 feet above MSL) is found on the flood plain of the middle fork of Salt Creek just east of the western county border (2). The highest elevation (1050 feet above MSL) is at Weedpatch Hill, southeast of Nashville (see Figure 7).

Bedrock topography (see Figure 8) of Brown County is characteristic of a dissected upland (ergo named the Norman Upland) surface with an average elevation of 900 feet. Uplift of the sandstone - shale plain and subsequent erosional processes have produced the picturesque landscape found today. The resulting topography is typical of an uplifted, maturely dissected peneplain and is common in the bedrock region of southern Indiana.



SCALE 1 : 250,000

(CONTOUR INTERVAL 100')

FIG. 7. TOPOGRAPHIC MAP OF BROWN COUNTY

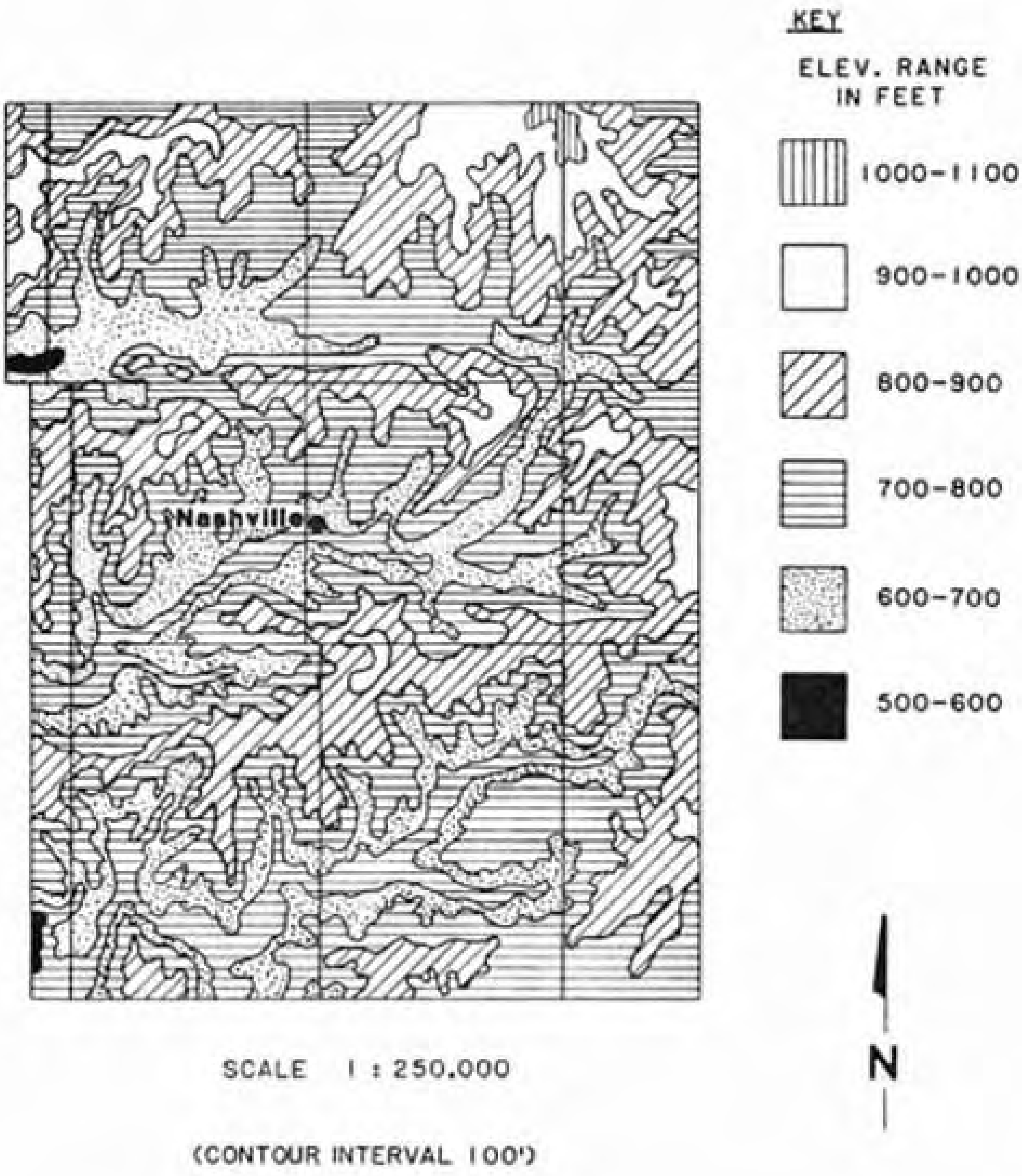


FIG. 8. BEDROCK TOPOGRAPHY OF BROWN COUNTY (43).

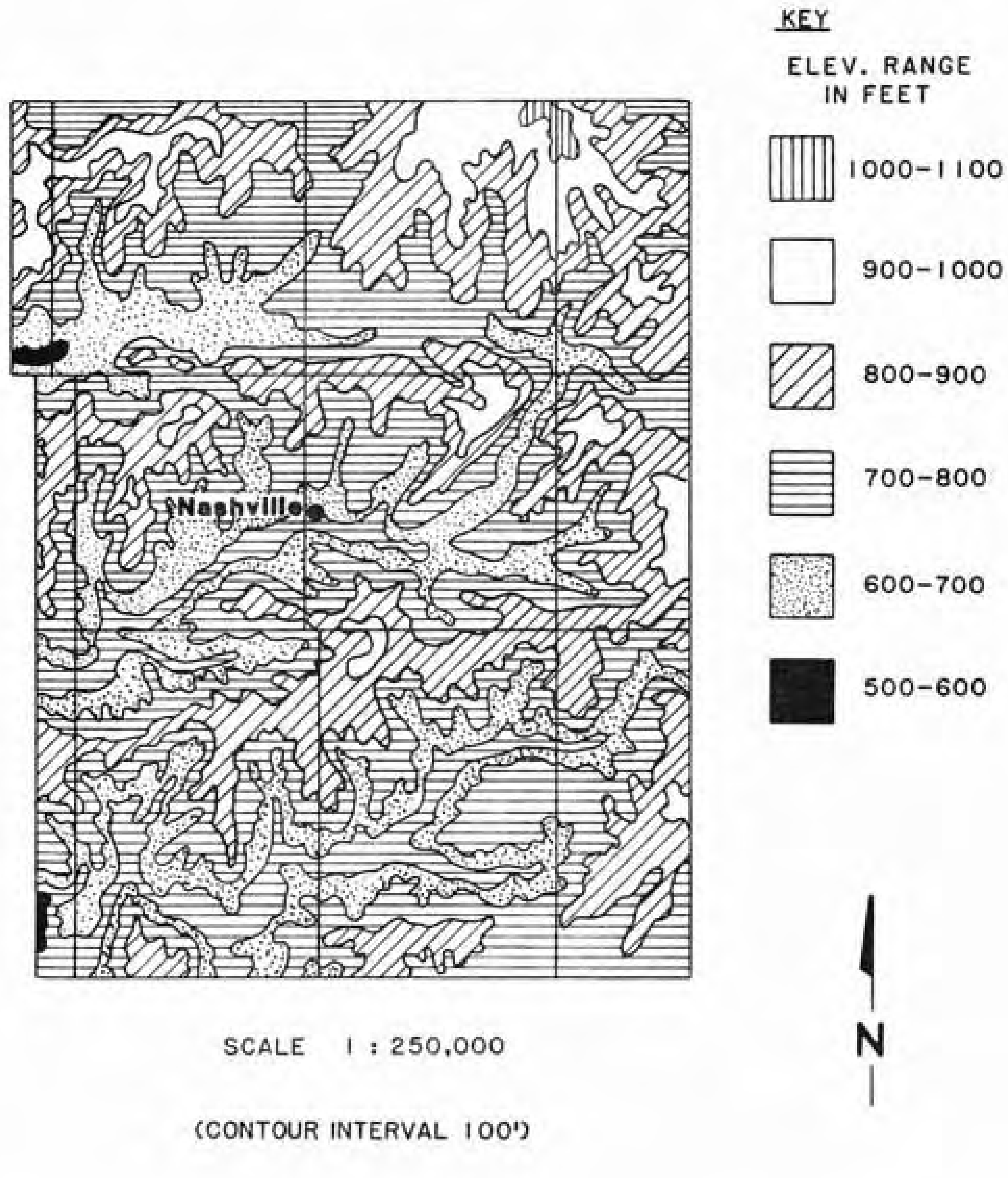


FIG. 8. BEDROCK TOPOGRAPHY OF BROWN COUNTY (43).

Three upland interstream areas exist in Brown County; between Camp and Bean Blossom Creeks in the north, between Bean Blossom and the North Fork of Salt Creek in the central part of the county and between the North and Middle forks of Salt Creek to the south. Minor spurs extend perpendicularly to the upland areas and are 125 to 250 feet lower in elevation.

Local relief along dissected areas of the bedrock upland ranges from 50-200 feet. The slopes in the eastern portion of the county are gently rounded, indicating that shale is the predominate rock type. The slopes in the western portion of the county are slightly more angular due to the presence of thin, more frequent, sandstone units.

Slopes are generally steep (30° to 70°) and are often benched due to differential weathering of the underlying sandstone and shale rock units. The valleys of south flowing streams are three to four times longer than those flowing to the north, due to a combination of differential weathering of the north and south facing slopes (eg., the south facing slopes erode faster) and the regional dip (5°) of the rock strata to the southwest.

Glaciation of the bedrock areas in the north and the southeast part of Brown County have rounded the slopes and subdued the relief. Thick Illinoian ground moraine deposits of moderate to gently undulating relief are found in the northern glaciated area of the county. The topography in the area becomes more rugged and the slopes steeper with increasing distance (eg., traveling east or west) from the valley of the west fork of Bean Blossom Creek. Slopes are more gentle in the southeastern glaciated areas and exhibit low to moderate relief (i.e., 20 to 50 feet). Relief in the small northeastern area glaciated during Wisconsinion time is more rugged than in areas affected by the Illinoian glaciation.

Numerous alluvial derived terraces composed of glacial materials are found in the valleys of Bean Blossom Creek and the north and middle forks of Salt Creek about 2-5 feet above the flood plain. Rock benches are common and are located 20-50 feet above the flood plains along the valley walls. Lacustrine terraces are located in the lower courses of the major stream valleys (20-30 feet) and the undissected surfaces are relatively flat and featureless.

Land Form and Engineering Soil Areas

The engineering soils of Brown County are developed on transported and residual materials. The transported materials include glacial and recent alluvium, colluvial detritus, windblown silt (loess), lacustrine deposits, and ground moraine. A blanket of loess up to 25 inches thick covers the entire county except in areas of severe erosion and fluvial activity. The loess blanket is not shown on the map as a unique engineering soil area, however, it is identified by a textural symbol (see right - hand side of the attached map). Colluvium is also not shown on the map due to scale limitations.

General descriptions of the engineering soil properties and characteristics are herein presented, however, considerable variation may be expected within any given landform - parent material association, particularly in areas of transported materials. Data for liquid limits, plasticity indexes, and ASSHTO classifications were obtained from the Soil Conservation Service (9) and are given in the descriptions of most of the engineering soils. Additional properties and characteristics developed on representative pedalogical soil series for each land form type are given in Appendix A.

Eolian (Wind-Blown) Deposits

Virtually the entire county is covered by loess of varying depths, except for areas of alluvial deposition and areas where erosion is severe, primarily where bedrock slopes are steeper than about 35 degrees. Loess depth is as much as 25 inches (24) in the western portion of the county and decreases eastward. Loess thickness is slightly greater in areas of Illinoian ground moraine.

The typical surface soil of the surficial loess deposits is a loam (A-4) or silt loam (A-4) which extends to a depth of 0 to 12 inches. The subsoil horizon is composed of a silty clay loam (A-4, A-6) which extends to a depth of 12 to 30 inches. The Martinsville soil series is commonly developed in areas of thicker loess.

The fine texture and non - cohesive nature of the loess are two of the chief causes of highway performance problems in Brown County. The loess soils in compacted subgrades and fills are highly subject to piping, pumping, and frost heave. Bearing capacity of the loess blanket is low to moderate, and the blanket is subject to sudden collapse upon wetting. Since the layer is thin, the practical consequences of such actions are minor. Reworking and leaching of the loess blanket has altered its original soil structure producing properties uncharacteristic of typical, basically unaltered deposits of loess (eg., a stable soil structure upon wetting).

Glacial (Ice-Contact) Deposits

Brown County contains deposits of Illinoian and Wisconsinan Age ground moraine. The Illinoian ground moraine is located in north-central and southeastern Brown County. Illinoian drift less than 10 feet thick is termed 'thin' Illinoian drift over interbedded sandstone - shale bedrock in this report. The Wisconsinan ground moraine is confined to the northeastern corner of the county and is generally less than 10 feet thick. There is no evidence of any terminal moraines in Brown County, if any ever existed, perhaps due in part to the long, post-glacial period of weathering and erosion.

Ground Moraine of Illinoian Age with Thin Loess Mantle

Illinoian ground moraine greater than 10 feet in thickness is located north of Bean Blossom Creek in north-central Brown

County and is part of the Butlerville Till member of the Jessup Formation (10). Topography of the Illinoian ground moraine varies from nearly flat to gently undulating, depending on the amount and degree of stream dissection. Gully slopes are generally steep, ranging from 40° to 65°, and lack the loess cover. The thickness of the loess blanket is less than 20 inches and is inversely proportional to the slope angle. The Illinoian ground moraine is extensively farmed in Brown County and usually requires some tile drainage which supplements the natural soil drainage. Areas of Illinoian ground moraine were identified by their characteristic white-fringed, dark centered gullies.

Surface soils of the Illinoian ground moraine are silty clays (A-4 to A-6) or clays (A-6 to A-7) which extend to a depth of 12-14 inches (9). Clay (A-7) is found below to a depth of 30 to 53 inches. Beneath the clay is a loam (A-4-0) or a silty clay (A-6-8) soil which grades into the heterogeneous, relatively unweathered parent material (A-6, ML) of the Illinoian ground moraine at a depth of 7 feet. Depth to bedrock varies from 10 to 35 feet[1] (11).

Local textural variation due to topography and the influence of varying loess thickness should be expected. The high areas, have slightly coarser surface soils and well developed soil horizons. The surface soils in the high areas range from a silty clay (A-6) to a clay loam (A-4). In the low areas, the soil is

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1 Water well logs north of Goshen Church report till thicknesses of 25-35 feet.

not drained as well as in the topographic highs and the surface soils texture is generally finer, usually a clayey (A-6, A-7) soil due to the accumulation of fines (silt and clay).

The engineering soil properties are similar for both high and low topographic positions. The sub - surface soils below 20 inches to a depth of 12 feet are moderately plastic (12). The liquid limit (L.L.) ranges from 25 to 39 and the plasticity index from 14 to 17. The sub-surface soils are highly overconsolidated and are relatively incompressible (9). The sub - surface soils are of high shearing strength and are relatively cohesive and possess a high angle of internal friction (13). Reported unconfined compressive strength values for similar deposits in Indiana range from 1-4 TSF (13). The dry unit weight ranges from 93 to 109 pcf. These soils are easily worked during compaction (14, p. 158) and commonly serve as construction materials in earthen dams due to their high, shear strength and moderate resistance to seepage and erosion.

The surface soils are silty and are suspectible to frost heave, due to a high seasonal groundwater table and excessive fines. This combination leads to a number of highway performance problems such as pumping. The bearing capacity of surface soils is less than the subsoils, however, the surface soils are generally overconsolidated due to dessication. The surface and subsurface soils are moderately to highly impermeable (9,34).

Thin Illinoian Ground Moraine

Thin Illinoian ground moraine is found in gullies and on steep slopes (greater than 30 degrees) in areas of thick Illinoian till and along flat upland areas, north of Bean Blossom Creek. The southeastern deposits of thin Illinoian drift in Brown County are scattered remnants marking the furthest advance of the Illinoian ice sheet in that area and are found only in upland areas. Erosion stripped the drift from sideslopes.

A silt loam (A-4-10) or silty clay (A-6-16) surface soil extends to a depth of 2 to 14 inches depending on the slope angle (i.e., deeper where slopes are less steep) (8). The silty clay soil is developed in the sloping areas and gullies where much of the original topsoil (see topsoil desciption of Illinoian drift) was eroded away. Beneath the surface soil is found silty clay (A-6) or clay (A-6(9)) to a depth of 33 to 84 inches, which is underlain by a thin (3 to 4 inch), stony layer of regolith above sandstone-shale bedrock. Depth to bedrock ranges from 3.5 to 10 feet and averages about six feet in sloping areas (all depths are measured normal to the surface).

The engineering soil properties and problems are similar to those of the thicker Illinoian drift deposits. The runoff coeficient of sloping areas is high due to the impermeable nature of the soil, resulting in erosion problems. The thin layer of moderately plastic (clay), near - normally consolidated residual soil developed above shale bedrock, may give rise to potential slope stability problems. Bearing capacity estimates in areas of thin drift must take into consideration the strength of this underlying residual soil layer.

Thin Ground Moraine of Wisconsinan Age with Thin Loess Mantle

The Wisconsinan ground moraine in northeastern Brown County is characterized by gently undulating land and was identified on the aerial photographs by the characteristic mottled, light - dark pattern. The loess cover varies from 3 to 15 inches in thickness (9) and is usually missing in the gullies. Wisconsinan ground moraine occupies less than one square mile in Brown County.

Surface soil of the Wisconsinan ground moraine is a silty loam (A-4) to a depth of 3 to 15 inches (9). Sub-surface soils are silty clays (A-5) or clays (A-6-7) to a depth of 2 to 4 feet, which are underlain by loamy soils (A-4) with varying percentages of clay. The lower portion of the loamy soil contains regolith from the underlying weathered bedrock surface. In some places a thin layer of Illinoian till (A-4 to A-5) is found between the Wisconsinan ground moraine and the bedrock surface. The Fincastle agricultural soil series is commonly found developed on the Wisconsinan ground moraine in Brown County (2).

Soils developed on the Wisconsinan ground moraine in Brown County are susceptible to frost heave, particularly in topographic lows, due to the annual occurrance of a seasonal high water table (depth of one to three feet (9)) and the high silt content of the soil. The subsoil is relatively impermeable due to the accumulation of clay in the well developed B - horizon, resulting in poor percolation and internal drainage and high surface runoff. Plasticity indexes generally range from 15-20 (9) with liquid limits of 20-40. The subsoil below 12 inches is moderately plastic with liquid limits and plasticity indexes on the high side of the given ranges. The subsoil is overconsolidated and relatively impermeable and incompressible, resulting in high resistance to erosion and piping (10). Compaction characteristics of the Wisconsinan ground moraine parent materials (ML-CL) make theme suitable material for use in earthen retaining structures (14, p. 158).

Colluvial Deposits

The colluvial soils represent less than 0.5 percent of the soils mapped in Brown County. These deposits are accumulations of fallen or slumped soil and rock debris which occur at the toe of steep slopes, particularly, in unglaciated areas of residual soils. Examples of small slumps can be found along the northern valley wall of the middle fork of Salt Creek near the town of Pikes Peak.

Colluvial deposit soil profiles are highly variable due to the random nature of transportation and deposition involved. Large slumps which moved as contiguous masses exhibit profiles similar to the local residual soils with a stony, disturbed soil zone at the sliding surface. A number of these large slides occurred in areas of deep (4 to 6 feet) residual soil where the slope angle ranged from 30° to 50° or greater. Smaller slumps and washed-down soils contain a mixture of silt, clay and rock fragments of varying sizes.

The bearing capacity of colluvial deposits and residual shear strength along slump failure surfaces are inherently low and construction on them are to be avoided, as reloading could lead to renewed movement. Slumped or washed-down colluvial material is of low bearing strength. Excavations at the toe of a slump or at the base of a slope may produce an unstable condition and should be avoided.

Fluvial Deposits

Fluvial deposits are landform - parent material associations formed in moving water. Fluvial deposits in Brown County include flood plains, recent alluvial terraces, and minor amounts of melt water - laid glacial sands and gravels.

Recent Alluvial Terraces

Recent river terraces are common along the valley walls of major creeks and their larger tributaries in Brown County and are located 3 to 5 feet above the flood plains. These terraces are nearly level and are generally composed of moderately well drained sandy - gravelly soils near the valley walls and less well drained, sandy - silty soils adjacent to the flood plain. Current scars are rare but infiltration basins are common, indicative of coarse textured soils which are generally well to moderately drained internally. These terraces are composed of reworked Illinoian outwash material and recently eroded sediments deposited by the present day streams.

The general soil profile of these deposits is variable, containing primarily sand and gravel and little clay and silt, reflecting the complex turbulent depositional environment of streams (15). Fine textured lenses of silt and clay are randomly found throughout the recent alluvial terraces but comprise a small percentage of the material found in these landforms. The layers of fine silt and clay found in the alluvial terraces probably formed in a slackwater - like environment in former topographic lows. The general soil profile shown on the attached map depicts the wide textural variations with depth that occur in the alluvial terrace, based upon agricultural soil series data and field sampling.

The surface horizon of the well-drained, near-valley-wall soils is a sandy loam (A-2-4) with some gravel or a silt loam (A-4) which extends to a depth of 9 to 19 inches (9). The texture of the subsoil is highly variable with thin (2 to 3 inch) clay layers and pockets of coarse sand and gravel which were identified during field sampling. Generally, the subsoil is a sandy silt-loam (A-4 to A-6) or silty sand (A-2) which extends to a depth of 30 to 60 inches. The subsoil is underlain by stratified sands, silts, and gravel (A-3) which reach to bedrock at a depth of 15 feet or more.

The surface horizon of the finer textured, moderately well drained alluvial terrace soils is composed of silty clays (A-4 to A-6) or silt loams (A-4) and is found to a depth of about 12-18 inches (9). The fine textured surface soils are characteristically found near the flood plain and in depressions in the alluvial terraces, The subsoil consists of clays (A-6 to A-7) and silty clays (A-6) which extend to a depth of about 25 to 90 inches. Stratified sands, silts and gravel (A-3), the characteristic parent material of alluvial terraces, are found beneath the subsoil to bedrock. Textural variations within the subsoil are common as fine textured subsoil may grade or abruptly change into coarser textured sediments, similar to those found in the coarse textured deposits.

Few engineering problems are associated with the coarse-texture, well-drained alluvial terrace soils (16). These deposits have a moderate permeability, which may even be excessive where extensive pockets of coarse sand and gravel are located. The bearing strength of the subsoils and parent material is moderate to high (16). The subsoils range from a soil of low plasticity (P.I ranges from 3 to 11) (9) to a non cohesive consistency. The compressibility of the surface soils is generally moderate to high as reported N values (19 and 20) are usually under 10 blows per foot. Therefore, loose surface soils and near-surface gravel pockets may yield large initial settlements upon loading. Local variations in soil texture of the alluvial terrace deposits infrequently give rise to differential settlements. Frost heave potential of the coarse-textured, well-drained soils is slight.

The finer-textured, moderately well-drained surface soils have moderate plasticity, with a P.I. range of 5 to 25 and L.L. range of 20 to 40 (9). The surface soils and those of the subsurface are compressible (16) and have a low bearing strength which increases with depth. Frost heave potential is high due to a high seasonal ground water table and the amount of fines in the soil.

Flood Plains

The soils developed on flood plains are divided into those found in sandstone - shale areas and those in glaciated areas, based on textural information obtained from adjacent county engineering and agricultural soil survey data.

In general, the flood plains are composed of well drained soils in relatively narrow deposits along the upper courses of the major streams and their tributaries. Poorly drained flood plain soils are found to the west in deposits near the Monroe County border along the major stream valleys.

Flood Plain Deposits In Sandstone-Shale Areas

Soils developed on flood plains in sandstone - shale areas are both well and poorly drained. The poorly drained soils are found primarily in topographic low areas along the major stream valleys. The areal extent of these poorly drained soils increases traveling westward where, near the western county border, the majority of the flood plain soils are poorly drained except close to the streams. The moderately well drained and well drained soils are common in the tributaries and towards the east in the major stream valleys.

The flood plain deposits are nearly flat, broken only by former and present day stream channel locations. The landform includes special features such as channel markings, old channel deposits and point bars. These features are primarily found in the valleys of the major streams and their larger tributaries. Flooding is frequent in topographic low areas and is seasonally extensive along the lower courses of the major stream valleys.

The general soil profile in the well drained areas consists of a sandy loam (A-2 to A-4) surface soil with trace gravel which reaches to a depth of 8-18 inches. The subsoil exhibits greater textural variation ranging from a sandy clay-loam (A-2-4) to a clay loam (A-4 to A-6) and extends to depth of 40 to 85 inches (2,9). Layers of silty clay (A-6) or coarse sand and gravel (A-1 to A-3) are common but are discontinuous and relatively small in extent. The underlying soils are low plasticity silty clays (A-4 to A-6) or sandy loams (A-4). Beneath the developed soil profile lie stratified sands and gravels with clay and silt layers (50 to 96 inches) to bedrock (depth ranges from 10-34 feet) (9,19,20).

The poorly drained soils contain a higher percentage of silt and clay and organic material. The surface soil is commonly a clay loam (A-6) with a trace organic matter which extends to a depth of 10 to 15 inches. The sub-surface soils vary less texturally than those of the well drained soils. Silty clay - loams (A-6) or clay loams (A-6 to A-7) are underlain by stratified sands and gravels with silt and clay.

The highway soil borings listed for Brown County in Table 7 (p. 53) are found along the glaciated and non-glaciated flood plain areas. The borings were made for bridge footings and are consequently located near the streams. Boring number 10 (17) is respresentative of well drained flood plain soils. The surface soil is composed of a sandy loam (A-2) with gravel to a depth of 6 feet. The subsurface soil extends from a depth of 6.0 to 14.5 feet and is a silt loam (A-4). Shale bedrock was struck at a depth of 14.5 feet. The sandy loam (A-2) top horizon had a low N-value of five(blows/ft.) indicative of low bearing capacity and high compressibility (22; pp 7-3-7-9), however, these values may be unrepresentatively low (23,p. 409). The underlying loamy soil is of medium density (see Appendix D), with a N-value of 20 indicating higher bearing strength. The reported N values may be high due to the negative pore water pressures developed during the penetration of a relatively dense silt deposit (23; p 127).

The sandy - silt, surface and subsurface (to 5 feet), well drained soils are generally found in a loose to medium dense (see Appendix D) condition. Differential settlements may be expected due to the heterogeneous, random distribution of sand, silt and gravel in the flood plain parent material. The underlying, stratified sands, and gravels, are usually found in a relatively dense condition, indicative of high bearing strengths (9) and relatively small initial settlements. Frost heave potential is high due to the high percentage of fines in the surface soils and a high ground water table (9,19). Large ranges in engineering properties which occur within small areas due to local textural variations necessitate thorough site investigations in order to locate and describe variations of soil type and condition.

Soil Borings 6 and 14 are typical of the somewhat poorly drained soils. Boring 14, located on the flood plain of the north fork of Salt Creek, found a silty loam (A-4) surface soil to a depth of about five feet. N-values of the surface soil were from 5 to 6 and have a range of reported unconfined compressive strengths of 0.3 to 0.7 TSF (20). A silty clay-loam (A-6-16) subsoil reached to bedrock at a depth of 13.5 feet. Blow counts (N=20) indicated moderately stiff clay (22, 7-4 to 7-7) of moderate-high bearing strength.

The general engineering properties of the somewhat poorly drained flood plain soils vary less with depth than the well drained soil. N-values are low (1-6) for the surface horizon and increase with depth. The blow counts for the subsoils range from 5 to 24 indicating the presence of firm to stiff cohesive soils. Liquid limits of the subsoil and surface soils range from about 25 to 40 and the plasticity index ranges from 5 to 15 (9). Frost heave potential is high and moderate settlements are expected in the normally consolidated, moderately compressible somewhat poorly drained flood plain soils.

Construction and maintenance of sanitary facilities and building in the poorly drained soil areas on the flood plains are hampered and restricted by flooding. The low bearing capacity of the surface soils may yield intolerable settlements.

Flood Plain Deposits in Illinoian Drift Areas

The flood plain deposits in the central - northern and southeastern glaciated areas of Brown County are relatively coarse textured, reflecting the composition of and proximity to the Illinoian drift source material and the turbidity of the flood plain depositional environment in these areas. The flood plains are relatively narrow with little soil variation attributed to topographic position. The soils are generally well drained and current markings and abandoned channels are scarce or absent.

The moderately well to well drained soils are located in the larger stream valleys and are similar in texture to the well drained flood plain soils in the sandstone - shale areas (2,3). The soils in the smaller tributaries are coarse textured and are excessively to well drained. The parent material of the moderately well drained flood plain soils in Illinoian glaciated areas exhibit less textural variation than the parent material of the well drained flood plain soils in the sandstone - shale areas. The surface soil is commonly a silty loam(A-4) to sandy loam which extends to a depth of 8 - 13 inches (9,16). The sub-surface soils are slightly more cohesive, ranging from a clay-loam (A-4 to A-6) or a sandy silt loam (A-4) which is found to a depth of 30 to 48 inches. Sandy loam(A-4) and silty loam(A-4) subsoils are commonly found near the streams. The subsoils are underlain by stratified silty sands and gravel or stratified loamy silts and clays.

In general, flood plain surface soils in glaciated areas are of low to moderate bearing strength (9,10) and are of moderate compressiblity (9). The subsurface soils composed of a sandy or silty clay loam are of low to moderate compressibility (10). Flooding is a problem but surface drainage is rapid, reducing the time of standing water after flooding. The potential for frost heave and pumping is high to moderate. The soil is moderately permeable.

Lacustrine Deposits

Lacustrine deposits in Brown County exist as high terraces along the lower and middle courses of the major stream valleys of Bean Blossom Creek and the north and middle forks of Salt Creek. These deposits are nearly flat; however, eroded slopes are as steep as one on one. Many towns are located on the lacustrine terraces due to the level topography and the relative elevation (20 to 30 feet) above the flood plains of these deposits.

The silt and clay parent material of the lacustrine terraces was deposited in a saturated condition in the still waters of temporary meltwater lakes which formed in the major east - west stream valleys when ice dammed their flows in adjacent Monroe County during the late Illinoian glacial period (6). The deepest, extensive deposits are found toward the west end of the valleys along Lakes Monroe and Lemon and near Belmont, where the glacial lakes were widest and the deepest (8). These deposits generally decrease in thickness traveling east from the Brown/Monroe County line. Deposit thickness at various locations from west to east are as follows: from 30 to 60 feet in eastern Monroe County along the middle fork of Salt Creek (6); about 14 feet southwest of the town of Belmont (3); approximately 10 feet northeast of Huber along the middle fork of Salt Creek; and from five to ten feet near Nashville (3). The lacustrine terrace deposits along Bean Blossom and the middle fork of Salt Creek are deeper than those found along the north fork of Salt Creek.

Most of the soils developed from the lacustrine parent material are well to moderately drained due to a moderate to high stream density. Poorly drained soils are commonly found near the valley walls of the more extensive deposits. The soil texture in general is homogeneous, however, local variations are found near the valley walls in the form of beach sands and gravels and deltaic deposits at the mouths of former tributaries. The deltaic deposits are composed of coarse-textured material washed down from the adjacent bedrock slopes during the Illinoian glaciation and are most common on the northern slope of Bean Blossom Creek (16). In eastern Monroe County the deltaic deposits are up to seven feet thick.

The predominant soils formed over the lacustrine terraces are silty clays of slow permeability. Loess deposits, 5 to 20 inches thick, cover the level areas but are thinner or completely absent in sloping areas due to erosion.

The surface soils are silty clays (A-6) or silt loams (A-4) found to a depth of 15 to 12 inches (8). Silty clays (A-6 to A-7) of moderate plasticity extend beneath the surface soils to a depth of 30 to 84 inches. The underlying soils vary from stratified fine sandy silts to silty clays and may be underlain by, or contain, preglacial or contemporaneous stream channel deposits.

The surface and subsurface soils are highly cohesive and are of moderate plasticity (P.I. of 4 to 20) which increases with depth (9,21). The liquid limit ranges from 25 to 40. The lacustrine terrace deposits are, in general, normally consolidated beneath the surface soils (1 to 3 feet) wherein dessication has resulted in an overconsolidated condition of the clays. Bearing strengths are low to moderate and the soils have low compressive strengths (16). Similar normally consolidated to slightly overconsolidated deposits in northern parts of Indiana have compressive strengths which range from 250-500 psf (13) and are of high compressibility. Differential settlements are of concern where the depth to bedrock is variable or local textural variations such as buried deposits of stream sands or gravels are found.

Frost heave potential is moderate to high due to the high percentage of fines and the seasonally high (one to three feet) ground water table in moderately sloping to flat areas. The lacustrine soils are difficult to compact due to the high plasticity. The soil is highly impermeable and is associated with high surface runoff but the deposit has a high to moderate erosion resistance.

Engineering problems associated with lacustrine deposits include: 1) slope instability; 2) poor septic absorption characteristics; 3) low bearing capacity; 4) highway pumping; 5) frost heave, and 6) high compressibility and consequent settlements.

Residual Soils of Sandstone - Shale Areas

About 75% of Brown County is covered by residual soils developed over sandstone - shale bedrock. The topography of these areas is characterized by moderate to steep slopes and level upland areas. Local relief is commonly over 100 feet. The high slope gradients contribute to the excessive surface drainage of the soils. The sideslopes and upland areas exhibit well defined breaks and benches in the western half of Brown County, resulting from differential erosion of the different bedrock types.

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The predominate bedrock type is a silty clay-shale. The New Providence shale, which underlies the residual soils of east central and eastern Brown County (3), weathers rapidly to a soft, moderately plastic, silty clay (see Appendix A-7). Intermittent sandstone units within the New Providence formation are few in number and seldomly exceed one foot in thickness (6).

The interbedded, sandstone - shale Locust Point formation predominates in the western part of Brown County. The shale in the formation is texturally and mechanically similar to the New Providence shale. The sandstone units are more common in the Locust Point formation but are rarely more than one to two feet in thickness. The sandstone units are more resistant to erosion than the shale and eventually weather to silty sandy residual soil.

Upland Residual Soil Areas

The residual soil thickness developed on the upland surfaces and the surrounding, gently sloping areas are greater in depth than in the adjacent more steeply sloping areas, and are covered by a thin blanket of loess. Loess thickness ranges from 3 to 15 inches and decreases with distance from the western county border and increasing slope angle.

The general soil profile is characterized by well-drained silty sandy soils or silty clayey soils. Terraced upland areas are indicative of different underlying lithologies which weather

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The general soil profile is characterized by well-drained silty sandy soils or silty clayey soils. Terraced upland areas are indicative of different underlying lithologies which weather to residual soils of correspondingly different textures. The silty sands are found over sandstone areas and the silty clays form over shale bedrock.

The predominant residual soil in Brown County is a highly cohesive, silty clay which forms over shale. The topsoil is commonly a silty clay-loam (A-6) or a silty clay (A-6 to A-7) which extends to a depth of 10 to 20 inches (2,9). The thickness of the subsoil generally decreases with increasing gradient or slope angle. Silty, sandy soil layers are not uncommon in the subsoil and represent the weathering of thin sandstone units. The subsurface soil is usually composed of silty clays (A-6 to A-7) or loamy clays (A-6) which extend to bedrock at a depth of about 26 to 72 inches. The weathered bedrock surface commonly contains stony regolith.

The cohesive soils are moderately plastic (P.I. of 5 to 20) with a liquid limit range of about 25 to 40, and are fairly impermeable, yielding subsequently low infiltration rates and high runoff coefficients (9.10). The surface soils usually are desiccated. The subsurface soils are of a soft to firm consistency. The soil along the bedrock surface is commonly wet and is of a soft consistency due to poor internal drainage and the underlying bedrock of low permeability. The upland residual soils are of moderate to low bearing capacity (10) and are moderately compressible. Sound bedrock is found at shallow depths (<7 feet) and has an RQD value (see glossary) over 70 (19,20). Frost heave potential is high to moderate and is greatest where the loess blanket is thickest. Piping is a problem where silty soils are used in residential water retention embankments. Pumping is a problem in compacted fills for roadways.

Silty sand residual soils are located in the flat upland areas when sandstone bedrock acts as a capping unit. Along these upland areas the soils are excessively drained. These deposits represent less than 15% of the upland residual soils (2). The surface soil is a sandy loam (A-4) or silty sand (A-2) which extends to a depth of 8-10 inches (9). The subsoil is commonly a sandy loam (A-4). The bedrock surface is at a depth of 20 to 54 inches below the surface. A stony regolith layer is commonly found along the bedrock surface. Residual soils developed over primarily shale bedrock are commonly thicker than those developed over sandstone - shale areas, as the shale weathers more rapidly and is less susceptible to surface erosion.

The sandy soils are of moderately high permeability and are well drained internally. The bearing capacity and compressibility are moderate to low (10). Due to the relatively thin soil cover, most structures are founded directly on solid bedrock. The sandy soils are associated with serious seepage as well as surface erosion problems with water retention structures in the residual soil areas. The sandstone bedrock is moderately impermeable and is moderately jointed.

Residual Soils Over Sloping Areas

The topography of these areas is rugged with slope angles ranging from 30 to 70 degrees. The soils are excessively drained and the loess cover is absent. Soil thickness in the steeply sloping areas is rarely more than three feet in depth (measured normal to the ground surface) and decreases with increasing slope angle. Generally, the soils formed in these areas are moderately to highly cohesive as the silty-sandy residual soils developed over the sandstone units are easily eroded and transported down slope.

The surface soil is generally a silt loam (A-4) which extends to a depth of 3 to 12 inches (9). The subsoil is a sandy silt-loam (A-4) or a silty clay (A-6 to A-7) which is found from a depth of about 6 to 24 inches. A moderate plastic clay (A-6 to A-7) is found beneath the subsoil to a depth of about 36 inches, where a stony layer of weathered regolith is found above bedrock.

The engineering properties are similar to the cohesive residual soils found in the level, upland areas. The soil is moderately plastic with low to moderate shear strength (9,10). Additional problems, besides those listed for the level upland areas, are high surface runoff and the consequent erosion and slope instabilities.

Bedrock Benches

Bedrock benches are present along the valley walls of the three major east-west creeks and their larger tributaries. They are located 20 to 50 feet above the flood plains and are nearly level. Rock benches are prominant along the valley walls of the north fork of Salt Creek, southeast of Trevlac, and south of Bean Blossom (6). The benches are evidence of the erosive action of the Illinoian meltwater which flowed through the valleys some time during glacial retreat. The soil profiles found over the bedrock benches were developed after the Illinoian meltwaters receded and are texturally similar to, although deeper than, the residual soils formed in the flat upland areas. Loess thickness ranges from 4 to about 15 inches (9).

The surface soil is a silt loam (A-4) or a silty clay loam (A-6) which is found to a depth of 26 to 36 inches (9). Small remnant patches of Illinoian age gravel are found at or near the surface in some places. A silty sand loam (A-4), or more commonly a silty clay (A-6 to A-7), extends beneath the surface soil to a depth of about 50 inches, and is underlain by bedrock of a stony sandy loam (A-4) or a stony silty clay (A-6 to A-7) (see Upland Residual soil description) to bedrock at a depth of 55 to 94 inches.

The residual soil formed over bedrock benches is generally cohesive and moderately well drained. Liquid limits for the subsoil range from 25 to 40 with plasticity values of 5 to 20 (9). The surface soil is silty and is less plastic. The soils are normally consolidated except for the more cohesive surface soils which are slightly over consolidated due to desiccation. The soil is of moderate bearing strength and compressibility.

Piping, pumping and frost heave potential of the surface soils is high due to the loess cover. Rock bench residual soils are poorly drained internally, resulting in high surface runoff and surface erosion. The deposit has a seasonably high water table (9).

Table 7. Brown County Highway Boring Data.

Site	Station	Off-set (ft)	Depth (ft)	AASHTO Class-ification	Tex-ture	Gravel %	Sand %	Silt Size %	Clay Size %	L.L.	P.L.	* P.I.	** S.L.	Blow Count	*** LOI
1	152+66	20 LT	0-3.0	-	Si.CL.L.	-	-	-	-	-	-	-	-	10	-
			3.0-9.0	-	Si.CL.L.	tr	-	-	-	-	-	-	-	15	-
			9.0-13.5	-	Clay	-	-	-	-	-	-	-	-	12	-
			13.5-	-	Sh.	-	-	-	-	-	-	-	-	-	-
2	153+15	20 LT	0-8.0	-	-	-	-	-	-	-	-	-	-	-	-
			8.0-	-	Sh.	-	-	-	-	-	-	-	-	-	-
3	156+80	11 LT	0.0-1.0	-	S.Gr.	-	-	-	-	-	-	-	-	7	-
			1.0-6.5	-	Si.CL.L.	-	-	-	-	-	-	-	-	8	-
			6.5-9.0	-	S.Gr.	-	-	-	-	-	-	-	-	24	-
			9.0-	-	Sh.	-	-	-	-	-	-	-	-	50+	-
4	988+00	35 RT	0.0-4.5	A-6	Si.CL.L.	-	-	-	-	-	-	-	-	50+	-
			4.5-11.5	A-6(8)	Si.CL.L.	13	5	55	27	31.7	20.3	11.4	-	47	-
			11.5-	-	Sh.	-	-	-	-	-	-	-	-	50+	-
5	990+40	19 LT	0-2.5	A-4(5)	Si.CL.L.	0	18	61	21	26.6	19.6	7.0	-	8	-
			2.5-8.5	A-6	Si.CL.L.	-	-	-	-	-	-	-	-	20	-
			8.8-10.0	A-6	Si.CL.L.	-	-	-	-	-	-	-	-	18	-
			10.0-	-	Sh.	-	-	-	-	-	-	-	-	-	-
6	990+87	14 LT	0.0-10.0	-	Si.L.	-	-	-	-	-	-	-	-	-	-
			10-19.0	-	Si.CL.	-	-	-	-	-	-	-	-	-	-
			19-21.5	-	Sh.	-	-	-	-	-	-	-	-	-	-
7	991+96	17 LT	0.0-2.5	A-4	Si.CL.L	-	-	-	-	-	-	-	-	6	-
			2.5-7.0	A-4(4)	Si.L.	0	15	73	12	26.3	19.8	6.5	-	3	-
			7.0-20	A-4(3)	Si.L.	-	-	-	-	-	-	-	-	1	-
			20-25	A-4	L.	-	-	-	-	-	-	-	-	3	4.01
			25-29	A-4(2)	Si.CL.L.	-	-	-	-	-	-	-	-	16	-
8	993+00	18 LT	0.0-7.0	A-4	Si.CL.L.	-	-	-	-	-	-	-	-	5	-
			7.0-15	A-4(1)	Si.L.	0	15	72	13	25.3	23.3	2.0	-	1	-
			15-23.0	A-4(0)	L.	-	-	-	-	-	-	-	-	3	-
			23-25.5	-	S.L.	-	-	-	-	-	-	-	-	18	-
			25.5-	A-6	Si.CL.L.	-	-	-	-	-	-	-	-	-	-

Table 7. (Continued).

Site	Station	Off-set (ft)	Depth (ft)	AASHTO Class-ification	Tex-ture	TEXTURE (%) Gravel %	Sand %	Silt Size %	Clay Size %	L.L.	P.L.	P.I.*	S.L.**	N	LOI***
9	102+1		0.0-3.0	A-2(0)	Si.L.	-	-	-	-	-	-	-	-	7	-
			3.0-6.5	A-2-4(0)	SiL-Gr.	41.9	26.6	31.0	0.6	N.P.	-	-	-	6	-
			6.5-8.5	A-4(0)	Si. O.	0.9	7.2	77.3	14.6	31.2	21.2	10.0	-	3	-
			8.5-	-	Sh	-	-	-	-	-	-	-	-	50+	-
10	102+84	18 RT	0.0-6.0	A-2-4	S.L. Gr.	-	-	-	-	-	-	-	-	5	-
			6.0-14.7	A-4	Si.L.	2.5	9.5	73.7	14.3	N.P.	-	-	-	20	-
			14.7-	-	Sh	-	-	-	-	-	-	-	-	50+	-
11	103+76	9 RT	0.0-1.0	-	CL.L.	-	-	-	-	-	-	-	-	-	-
			-9.8	-	Si.CL.	-	-	-	-	-	-	-	-	-	-
			9.8-10.3	-	SL.	-	-	-	-	-	-	-	-	-	-
			10.3-	-	Sh	-	-	-	-	-	-	-	-	-	-
12	104+01	17 LT	0.0-3.5	-	Si.CL.	-	-	-	-	-	-	-	-	-	-
			3.5-7.0	-	Si.CL.	-	-	-	-	-	-	-	-	-	-
			7.0-	-	SL.	-	-	-	-	-	-	-	-	8	-
13	104+24	15 LT	0.0-6.0	A-4	Si.L.	-	-	-	-	-	-	-	-	14	-
			6.0-10.7	A-7-6	Si.CL.L.	-	-	-	-	-	-	-	-	-	-
			10.7-13.5	-	S.L.	-	-	-	-	-	-	-	-	>50	-
			13.5-	-	Sh	-	-	-	-	-	-	-	-	7	-
14	54+00	27 LT	0.0-0.5	A-4	Si.L.	-	-	-	-	-	-	-	-	20	-
			0.5-13.5	A-6(16)	Si.CL.L.	-	-	-	-	-	-	-	-	-	-

* Plasticity Index; the range of plastic behavior; LL-PL=PI
** Shrinkage Limit;
*** Loss of Organics upon Ignition

Table 7. (Continued).

Site	Station	Off-set (ft)	Depth (ft)	AASHTO Class-ification	Tex-ture	TEXTURE (%) Gravel %	Sand %	Silt Size %	Clay Size %	L.L.	P.L.	P.I.*	S.L.**	N	LOI***
9	102+1		0.0-3.0	A-2(0)	Si.L.	-	-	-	-	-	-	-	-	7	-
			3.0-6.5	A-2-4(0)	SiL-Gr.	41.9	26.6	31.0	0.6	N.P.	-	-	-	6	-
			6.5-8.5	A-4(0)	Si. O.	0.9	7.2	77.3	14.6	31.2	21.2	10.0	-	3	-
			8.5-	-	Sh	-	-	-	-	-	-	-	-	50+	-
10	102+84	18 RT	0.0-6.0	A-2-4	S.L. Gr.	-	-	-	-	-	-	-	-	5	-
			6.0-14.7	A-4	Si.L.	2.5	9.5	73.7	14.3	N.P.	-	-	-	20	-
			14.7-	-	Sh	-	-	-	-	-	-	-	-	50+	-
11	103+76	9 RT	0.0-1.0	-	CL.L.	-	-	-	-	-	-	-	-	-	-
			-9.8	-	Si.CL.	-	-	-	-	-	-	-	-	-	-
			9.8-10.3	-	SL.	-	-	-	-	-	-	-	-	-	-
			10.3-	-	Sh	-	-	-	-	-	-	-	-	-	-
12	104+01	17 LT	0.0-3.5	-	Si.CL.	-	-	-	-	-	-	-	-	-	-
			3.5-7.0	-	Si.CL.	-	-	-	-	-	-	-	-	-	-
			7.0-	-	SL.	-	-	-	-	-	-	-	-	8	-
13	104+24	15 LT	0.0-6.0	A-4	Si.L.	-	-	-	-	-	-	-	-	14	-
			6.0-10.7	A-7-6	Si.CL.L.	-	-	-	-	-	-	-	-	-	-
			10.7-13.5	-	S.L.	-	-	-	-	-	-	-	-	>50	-
			13.5-	-	Sh	-	-	-	-	-	-	-	-	7	-
14	54+00	27 LT	0.0-0.5	A-4	Si.L.	-	-	-	-	-	-	-	-	20	-
			0.5-13.5	A-6(16)	Si.CL.L.	-	-	-	-	-	-	-	-	-	-

* Plasticity Index; the range of plastic behavior; LL-PL=PI
** Shrinkage Limit;
*** Loss of Organics upon Ignition

Engineering Problem Descriptions of Brown County

General

The following section is devoted to the engineering problems of Brown County and is included in order to present the engineer or construction supervisor with a more accurate picture of field conditions and potential problems. Design suggestions must be augemented with experience and adjusted for specific site conditions.

The report is divided into the following subsections:

A) Construction Materials Performance
B) Excavation and Foundation Performance
C) Slope Instabilities
D) Other Highway Problems
E) Water Related Structures
F) Waste Disposal Problems
G) Summary of Engineering Problems

Construction Materials Performance

Aggregate Supply

Brown County lacks abundant deposits of sand and gravel. Alluvial terrace deposits contain more sand and gravel than any other landform in Brown County, however, excessive fines (silt and clay) require prohibitive expenses for washing and grading, which minimizes the exploitation of these deposits as aggregate sources (9).

Lack of a local aggregate supply means that quality highway subcoarse materials must be trucked in from nearby counties. The alluvial terrace materials in Brown County are susceptible to frost heave, drainage problems and do not meet general AASHTO grading requirements (Designation M147) for subbase and base course use.

Steel and Concrete Corrosion

Concrete

The majority of the soils of Brown County are highly to extremely acidic (8). The well to moderately well drained soils of the bedrock, terraces and flood plain areas are extremely acidic (pH 5.2-4.5) (2). The relativily high acidity of the soils promotes corrosion, and affects the performance of poor quality concrete and metal structures (pipes, etc.) lying on, or buried in the ground.

Concrete corrosion was particularly severe in the flood plains where concrete of poor quality was used in the construction of a number of privately owned structures such as walkways, footings for light poles and other small structures and abutments of privately owned bridges (49). The concrete was found to be pitted and eroded, resulting in considerable loss of compressive and shear strength. Corrosion was observed to be a minor aesthetic problem (minor surface pitting) for good quality concrete under the most adverse conditions (constant or frequent wetting).

Steel Pipe Corrosion

A large portion of the underground pipes used for the construction of the public water works in Brown County are steel. Metal pipes generally have a useful life span of at least 40 years (27), but this figure is reduced to about 15 years (52) because of the chemical attack by the acidic groundwater conditions. The flood plains, where most of the buried piping is located, is very acidic (pH 5.0-4.5; 8).

In May, 1984, the cost estimation for the replacment of the steel pipes remaining in Brown County, by the County Highway Department, was around six million dollars for the next 10 years. This value is based upon the length of buried pipe and current prices of equivalent lengths of metal pipe. This figure represents an annual cost of approximately $600,000 a year, which is a staggering amount in terms of the annual budget allocation of the county highway department for such maintenance projects. The highway department has switched to the use of aluminum pipes for replacement of the steel pipes and for use in culvert design. The aluminum pipes have a higher resistance to aggressive groundwater, are lighter, easier to place, require fewer connections, and have a lower cost-per-foot length price.

Compacted Materials

The following is a brief discussion of selected soils frequently used in compacted fills or pads. A summary of all deposits is found in Table 15 in the Report Summary, page 105.

<u>The Illinoian glacial drift</u> deposits (ML-CL) have fair-good workability (14) and possess a high shear strength upon compaction. The soil provides a strong, low permeable barrier and is an excellent material for dam construction. The resistance to erosion is moderate, as is the potential for piping. As a subgrade for county or state roads, the compacted till will provide adequate bearing support, but is subject to frost heave and pumping problems under concrete. Compaction is best accomplished by a rubber tired or sheepsfoot roller. Compacted dry unit weight ranges from 90 - 130 PCF (34).

<u>Lacustrine soils</u> (ML-CL) are difficult to compact, and compaction of these moderately plastic clays is best accomplished by a sheepsfoot roller. Close control of the moisture content must be maintained (34). The compacted soil is susceptible to pumping, frost heave, and sideslope problems. The compacted soil has slow permeability, but is not recommended for use in dikes, embankments or drainage canals, because of low erosion resistance; neither should it be used in water retention structures, where seepage is critical. Similar lacustrine soils have been used for compacted soil blankets in sanitary landfills in neighboring

counties, because of the flexibility of the compacted material of low permeability (8).

The residual soils (CL-ML) are, for the most part, cohesive and have moderate workability (14). Compaction is best accomplished by a sheepfoot roller. Compacted residual soil has moderate shear strength and has a very low permeability (34). The compacted soil is subject to moderate pumping under concrete pavements and moderate frost heave problems. Piping potential is low to moderate for the more cohesive soils, but moderate to high for the silty/sandy residual soils. Mixing of the different textures usually produces a higher shear strength, better workability, and a lower piping potential, making combined compacted residual soil excellent core material for earthen dams. Unfortunately, both residual textures have a moderate susceptibility to erosion and must be covered with erosion resistant material in canals or levees. This soil is often used in numerous small earthen dams found in the non-glacial bedrock regions of Brown County, and performs satisfactorily (49).

The alluvial terrace soils (SM-ML) are moderately graded and easy to compact to a dense state (dry unit weight ranges from 105-135 PCF). The high percentage of fines in the soil will cause moderate pumping and severe frost heave problems along county roads. The compacted soil has a good to excellent bearing strength (9), a low compressibility, and a high resistance to erosion, but is subject to piping problems. Therefore these soils are not suitable for use in water retention structures (3), except as a shell material for the larger dams, because of the high erosion resistance and shear strength. The compacted soil is best used in foundation support or as a highway subgrade below the frost level.

Shale Fill and Embankments

The construction of the state highways and some of the larger county roads have required numerous rock cuts and fill to traverse the rugged, highly dissected bedrock terrain of Brown County. The use of the excavated shale bedrock from the neighboring cut areas for the construction of fills and/or embankments was and still is a common practice throughout much of Indiana (52). The problems which plague the use of shale in embankments and fills arise from the compaction of mechanically strong shales which eventually weather into a unstable soil-like material in which large settlements and slope failures are likely.

Settlement of old shale embankments was observed north of Nashville on State Road 135 and along State Road 46, just west of the Brown County border (49). These shale fills, like many other older shale fills in Brown County, were constructed without consideration, or proper understanding of the compactive properties, or long term behavior of the shale. Since shale is a cheap and plentiful alternative to other fill materials, a system has been developed to predict the behavior of compacted shale material in order that it may safely be utilized as a fill material.

A critical aspect of compacted shale behavior is the long term response. Certain shales are subject to slaking more than others, and will weather to a soil-like material. The degradation of the shale into soil causes collapse in the original compacted structure of the fill. The slaked soil collapses in the voids that have remained after compaction. Settlements and loss of shear strength follow. The amount of settlements depends upon the size of the voids which remains after compaction. For this reason, it is important to have stringent compaction specifications (size of lifts, moisture content, and compactive effort) in an effort to control the size of the voids formed.

The slake durability (S.D.) tests produce an accelerated weathering process, and indicate which shales degrade into soil-like material more rapidly. The S.D. test procedure is described in Oakland and Lovell (28). The slake durability index, I_d (2), is a test result value which represents the percentage of the shale sample that failed to slake into soil after the second test cycle. The weight of the slaked material is simply lost as it passed out of the partially submerged wire meshed tumbler. The slake durability index (second cycle) shall be calculated as follows:

$$I_d(2)=\frac{W-C}{B-C}x100$$

where

B = weight of drum plus oven-dried sample,

W = weight of drum plus oven-dried sample retained after the second cycle, and

C = weight of drum.

The slake durability index ranges from 0 to 100. The lower the value, the higher the percentage of the shale sample that slaked into soil during the test, (a S.D. value of zero means the sample slaked completely into a soil material). Shale samples with an S.D. value less than 80 are termed 'soil-like' and are expected to weather to a soil over the service life of the fill.

The Franklin rating system, Figure 9, combines the slake durability index with either the point load test (when S.D. value is greater than 80) or with the Atterburg limits (when S.D. value is under 80). The point load test is applied to classify the more durable shales, and the plasticity index is used to rate the others. The Franklin rating system tries to incorporate the compaction properties and the slaking potential of the shale in order to identify potentially dangerous combinations.

The point load test, I_p (50), (see Glossary) must be adjusted for the use of the recommended sample size of 50.0 mm (28). The standard method for calculating the plasticity index is given by AASHTO T90-70. This combination of test values will allow one to arrive at a 'R' number for the shale. This 'R' value has been related to strength parameters on Figure 10. The 'R' values listed on Table 8 for all shales of the Borden group are low (<4.5). This indicates that the shales of Brown County

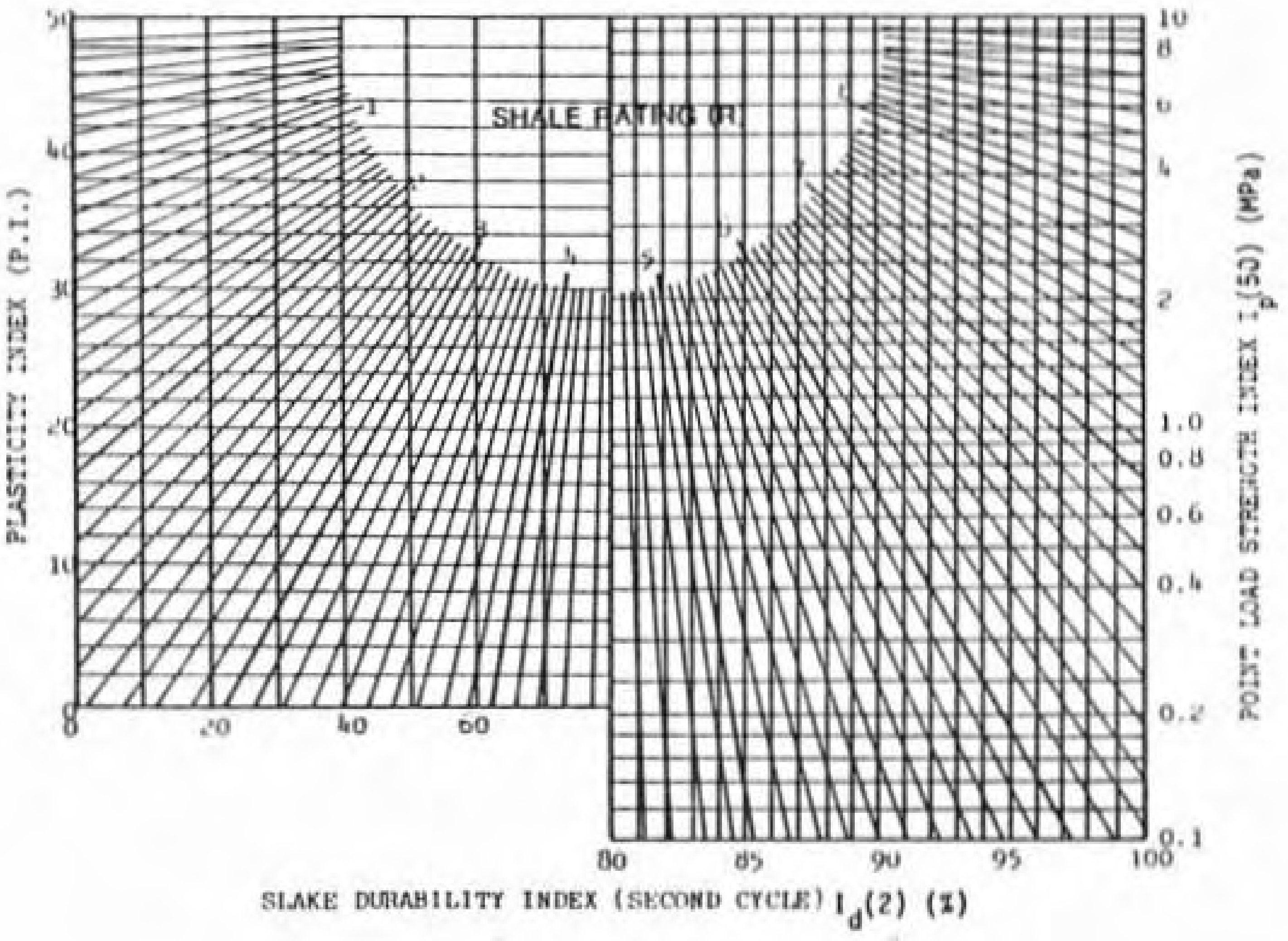


FIGURE 9. Shale Rating Chart (28)

Table 8. Average Properties of Compacted Shales Found in Brown County. (28 and 30)

Rock Name	S.D.I	L.L.	P.I.	Estimated Franklin Rating R#	Max. Dry Density (PCF)	Optimum Moisture (%)	CBR 95% of Optimum	Rocklike or Soillike
New Providence Shale	69-71	27-34	5-10	4.2	119-121	10-13	8-11	soil
Locust Point Form (upper)	67.6 (26.9)A	27-28	8	≤3.8	119-122	11-13	8-11	soil
(lower)	73 (42.6)A	27.2	8-9	≤4.2	123-127	10-11	10	soil

A - Based upon 500 revolutions. The recommended laboratory (Oakland, 1982) procedure suggested that the shale durability index be computed after 2-200 resolution cycles. It has been found that beyond this recommended limit, the constant between soil-like soft shales is reduced.

B - Based upon a single cycle of 200 revelations.

Table 9. Index of Crushing and Coefficient of Variation for Impact Compaction Samples (29)

SHALE	EFFORT LEVEL $\frac{kN-m}{m^3}$	INDEX OF CRUSHING: MEAN VALUE (%)	INDEX OF CRUSHING: COEFFICIENT OF VARIATION (%)
NEW PROVIDENCE	1) 527	25.7	10.4
	2) 790	37.6	5.6
	3) 1451	43.9	5.0
	4) 2414	57.7	3.9

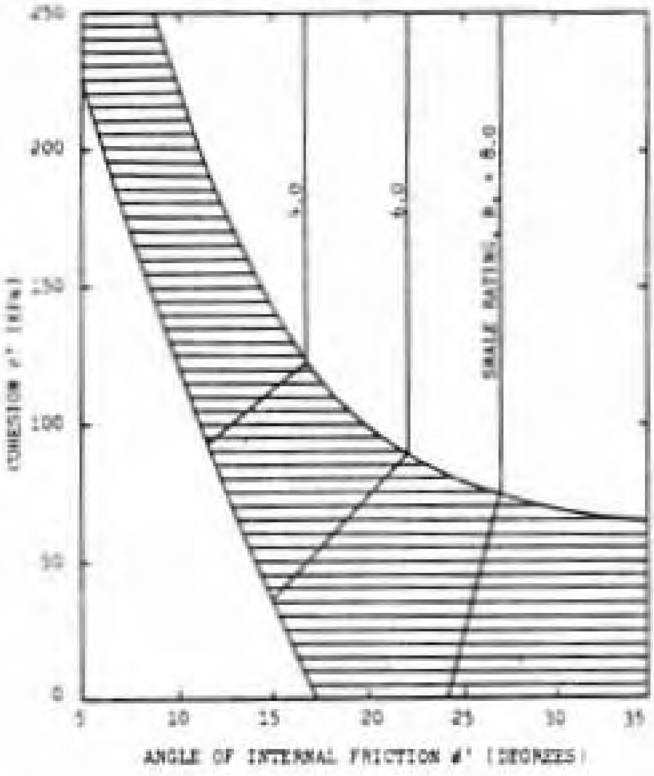


Figure 10. Trends in the Shear Strength Parameters of Compacted Shale Fills as a Function of the Shale Quality (28)

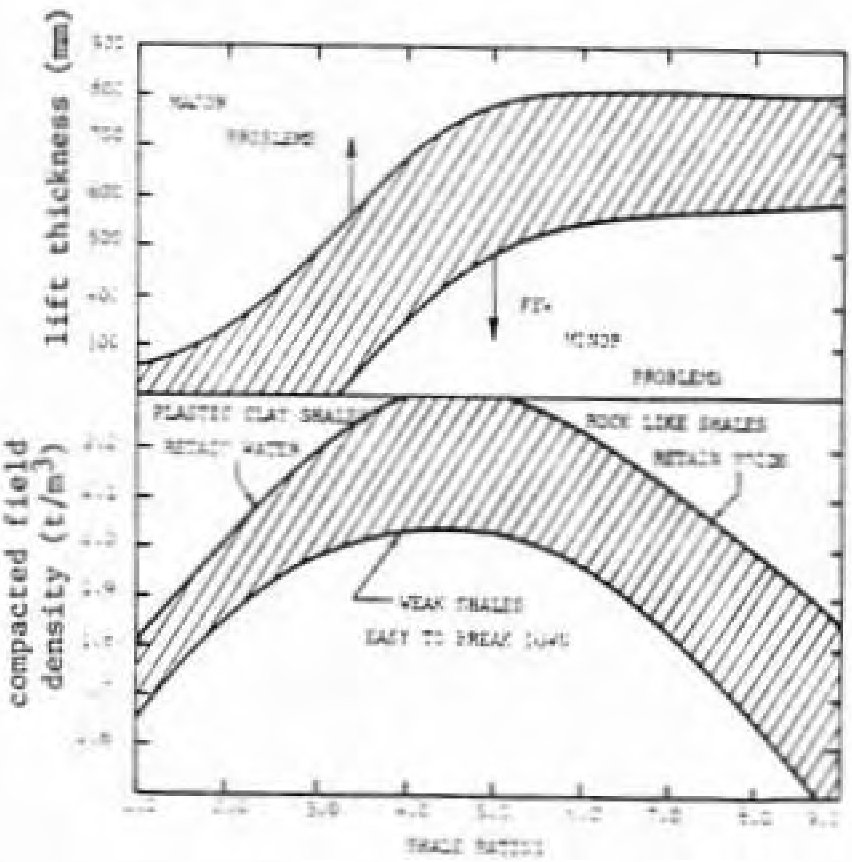


Figure 11. Tentative Correlations Between Shale Quality, Lift thickness and Compacted Densities (28)

will degrade into a soil-like material. Yet, the compaction data indicate the Brown County shales are hard and difficult to compact. This is a dangerous behavior for non-durable shale that is used in a compacted fill. Future shale fills constructed in Brown County must be designed from the viewpoint that the shale material will degrade into a soil with time. The design of the embankment must consider sideslope instability, if proper compaction control is not used, due to loss of strength,and settlements, upon the transformation of shale to soil.

The most hazardous shales are those which do not break down easily under compaction, but in time, weather to a soil-like material. The index of crushing value is used to indicate the change of the mean particle size with compaction,or the crushability of the shale. The larger the value, the easier it is to break the shale into smaller pieces, thus reducing the void spaces during the compaction process (i.e., producing a denser medium). Rocks which are difficult to crush (eg., to compact) are termed 'hard' while easily crushed materials are termed 'soft'.

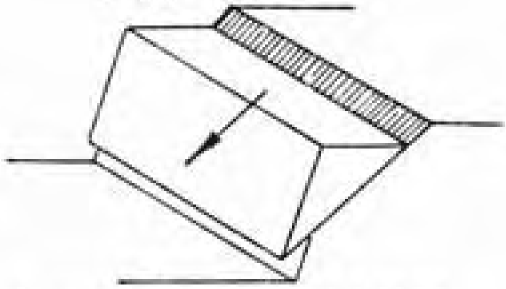
Table 9 lists the index of crushing for the New Providence shale which composes the eastern half of the bedrock geology of Brown County. The values listed indicate that considerable compactive effort is required to break up the shale pieces (29). The shale compaction test reports, in Appendix B, indicate that the New Providence shale and the younger, overlying formation (Locust Point) are 'hard', meaning they are mechanically strong and difficult to break up. Increased field breakdown, leading to a denser medium, may be accomplished by increasing the compactive effort (i.e., a heavier roller), or decreasing the size of the lifts (See Figure 11).

The use of the predominately shale bedrock found in the western portion of the county for fill material must also consider the presence of thin sandstone/siltstone layers which decrease in frequency traveling to the east. These sandstone units are more common in the upper part of the Borden group (the Locust Point formation). Inclusion of these mechanically strong and durable rock types will cause compaction problems. The compactive effort needed to break down the shale may be insufficient to break down the sandstone pieces into the design lift thickness. Thus, the inclusion of harder more durable material will create differential settlements and make compaction specifications difficult to obtain.

Slope Instabilities

Slope instability problems in Brown County are divided in to soil and rock related failures (see Figure 12). Soil failures are most commonly associated with the slopes of lacustrine terraces and steep-sloped areas of residual soil. Rock slope failures are usually toppling blocks of undercut, sandstone unit, cantilevers along highway road cuts.

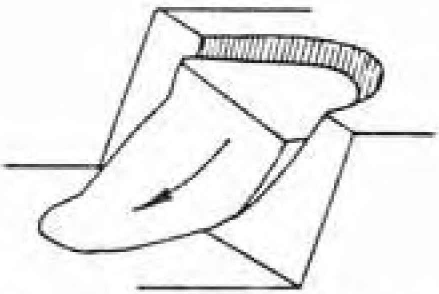
While most of the failures in Brown County are associated



Plane Failure

Plane failure in rock with highly ordered structure such as slate.

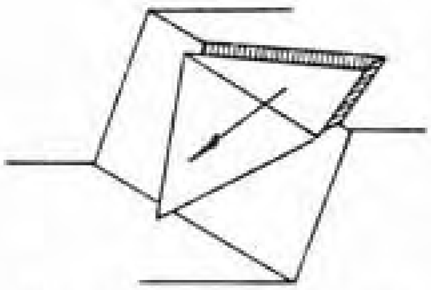
As shown in the margin sketch, plane failure occurs when a geological discontinuity, such as a bedding plane, strikes parallel to the slope face and dips into the excavation at an angle greater than the angle of friction. The calculation of the factor of safety follows precisely the same pattern as that used for the single block. The base area A and the weight W of the sliding mass are calculated from the geometry of the slope and failure plain. A tension crack running parallel to the crest of the slope can also be included in the calculation.



Circular Failure

Circular failure in overburden soil, waste rock or heavily fractured rock with no identifiable structural pattern.

When the material is very weak, as in a soil slope, or when the rock mass is very heavily jointed or broken, as in a waste rock dump, the failure will be defined by a single discontinuity surface but will tend to follow a circular failure path. This type of failure, illustrated in the margin sketch, has been treated in exhaustive detail in many standard soil mechanics textbooks.



Wedge Failure

c. Wedge failure on two intersecting discontinuities.

When two discontinuities strike obliquely across the slope face and their line of intersection daylights in the slope face, the wedge of rock resting on these discontinuities will slide down the line of intersection, provided that the inclination of this line is significantly greater than the angle of friction. The calculation of the factor of safety is more complicated than that for plane failure since the base areas of both failure planes as well as the normal forces on these planes must be calculated.

Figure 12. Main Types of Slope Failures (From Hoek and Bray, 31).

with engineering works, naturally occurring failures are also found. Old, natural soil slope failures were observed in eastern Brown county in thick, sloping residual soil areas. Failure occurred when the toes of these slopes were undercut by nearby streams. Natural slopes in the lacustrine deposits are very stable (8) and usually free of failures. Natural rock slopes are also stable as the conditions which produce rock slope instabilities (intersecting joints, mylonite zones, and dipping bedrock strata) are not present.

This section describes the site conditions for various engineering works in susceptible landform-parent material associations, for which the geotechnical and field engineer may expect slope stability problems. The following slope stability analysis and problem discussions are based on regional engineering soil data (8,9), roadway soil survey data of similar deposits (21), field observations, and engineering judgement. The analysis results and design suggestions given are not "cookbook" formulas, as specific site conditions vary considerably within any landform. However, the analysis results may serve to educate the engineer as to what conditions may be expected in the field, and provide preliminary guidelines for design.

Soil Failures

<u>Soil Slope Failures in Lacustrine Clays</u>

Circular failures and slumping are common in deposits of

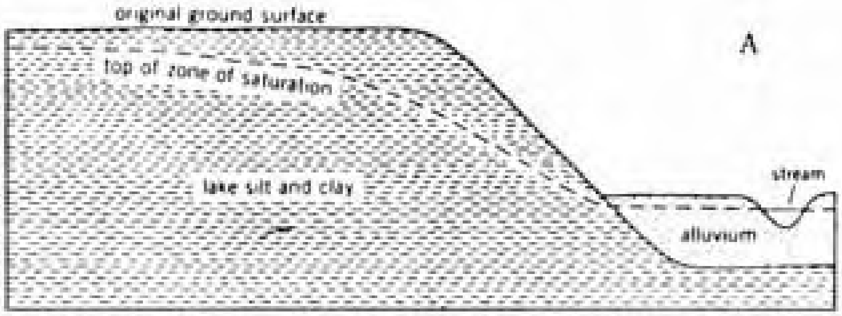
<u>lacustrine clays</u>, particularly where the natural slopes are altered by construction or runoff is increased. Circular slides occur both as well defined failures with two to three foot scarps and as less well-defined, slump-like failures. The conditions for slope instability include: removal of toe support by rapid excavation, overly steep slope angles, saturation of the slope, and overloading of the head of the slope.

A circular failure was observed near Belmont along an artificially graded slope at the base of a housing structure. The slope was apparently cut too steeply (original cut angle estimated at 35-45 degrees), even though some of the stable natural slopes nearby were nearly as steep. Surface drainage from surrounding soil areas flowed over the slope, resulting in frequent recharge and subsequently a saturated soil condition. This failure was perhaps due to overloading caused by surface saturation of the soils and/or oversteepening of the natural slope. This case of slope failure is representative of the construction-related slope instabilities which occur in the lacustrine terrace deposits in Brown County.

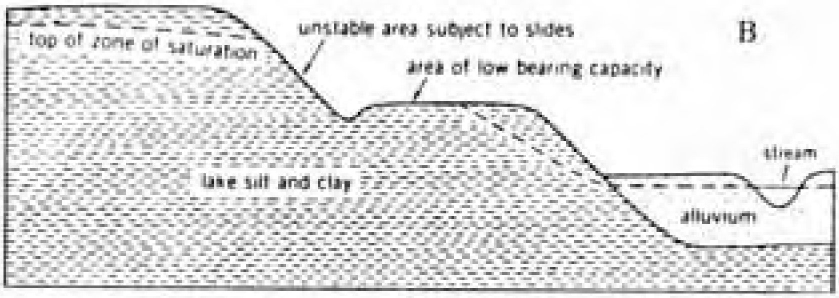
The slope stability problems caused by construction in lacustrine clays are due to the behavior of contained water and low shear strength. Lacustrine clays have high water retention capacities but have slow permeability and do not transmit contained water readily. The lacustrine soils are composed primarily of clay and silt sized particles which hold the contained water in place by capillary tension and as water bound to the surface of the clay particles. This 'bound' water is not affected greatly by gravitational drainage forces and it may take months for a lacustrine clay deposit to adjust to a revised ground water regime (23, 25).

Natural slopes in the lacustrine clays are not reliable guides for cut angles of artificial slopes, the stability of the natural slopes is based upon long term, CD (see Glossary), shear strength parameters where both cohesion and friction of the soil are mobilized. (see Figure 13). When a cut is made in a saturated lacustrine clay deposit, exposing the ground water table, the adjacent soil and water support is removed, resulting in an overloaded unstable condition. The rapid loading of the slope does not allow for the dissipation of excess hydrostatic pore water pressures prior to critical stability conditions. In such a case where there is neither consolidation or drainage of the soil during loading, the friction angle is assumed to be zero and the shear strength is determined from an unconsolidated, undrained test (22). This results in a larger stress difference. When the stress difference is large enough, the shear strength is overcome, and failure occurs. When a cut is made in a normally consolidated deposit, as is the case here, the stress difference is the greatest right after construction and decreases with time as the GWT adjusts to a new equilibrium position.

The best design approach is to reduce the slope angle (see Figure 14), or make the cuts in a number of stages, allowing the GWT to adjust to the new slope angle with each succeeding cut.



In A, top of zone of saturation has become adjusted to this slope over a long period of time. Most rainfall runs off and top of zone of saturation fluctuates little.



In B, internal drainage of lake silt and clay is so slow that slumping is likely before top of zone of saturation can achieve equilibrium with new ground surface.

Figure 13 . A, Cross section showing natural slope on lake silt and clay, and B, Same cross section showing new cut that exposes saturated, unstable material. (8)

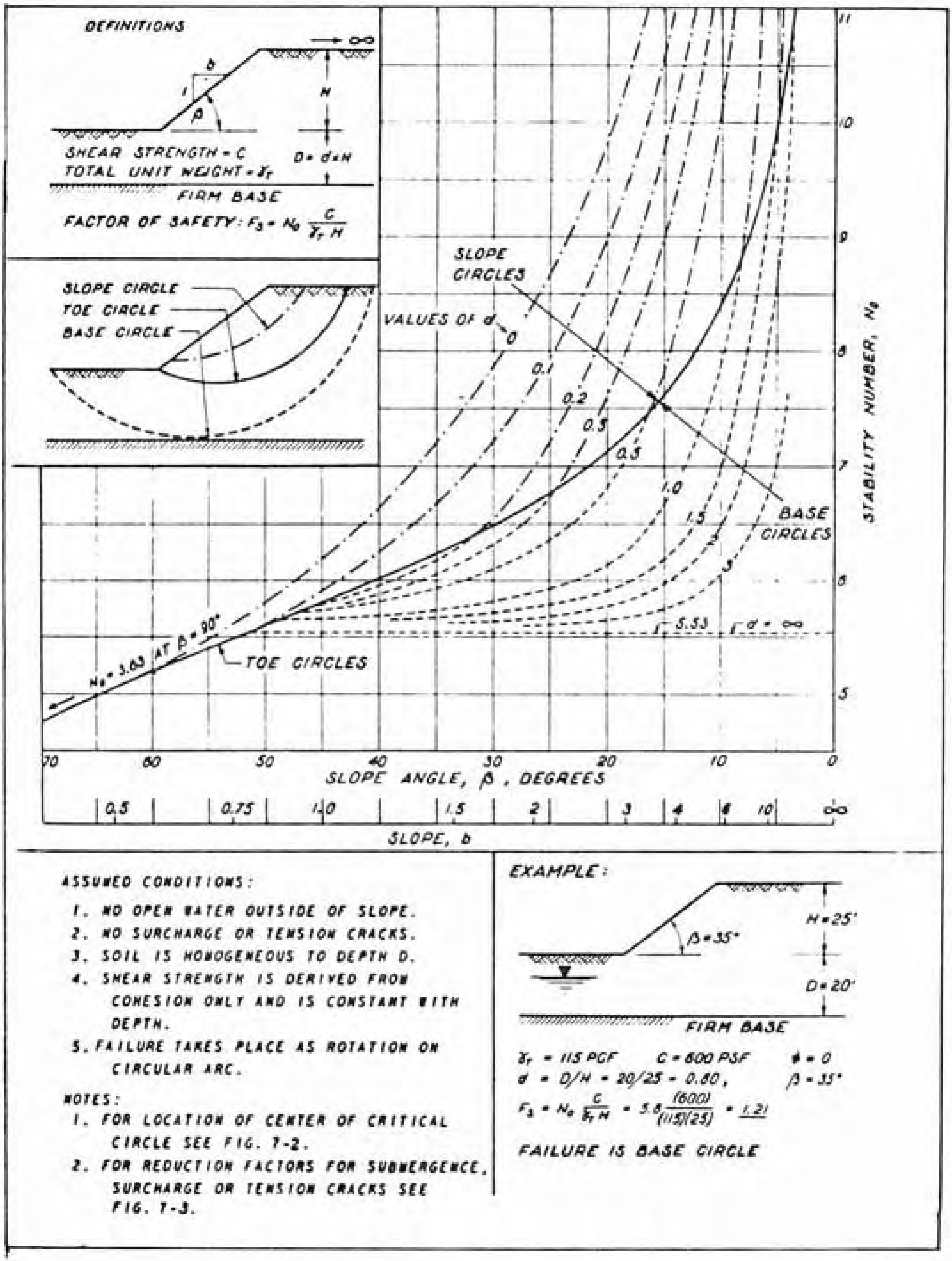


Figure 14. Stability Analysis for Slopes in Cohesive Soils ($\phi = 0$) (22).

The control of surface runoff by redirection, and placement of septic fields away from sloping areas also reduces the likelihood of failure. Internal drainage methods (pipes) are not considered an effective aid in reducing slope stability problems due to the slow permeability of the lacustrine clays. Depth of bedrock also effects the stability of the slope (see Figure 14). The shallower the depth to bedrock, the higher the factor of safety.

Slope Failure in Residual Soils

Planar failures occur in moderate to steep sloping (30 to 45 degrees) residual soil areas. Initial instability is usually caused by the loss of toe support due to excavation along the side of a road. Slope failures along road cuts are more common in the eastern portion of the county where thicker, more plastic, residual soils are developed over the New Providence shale.

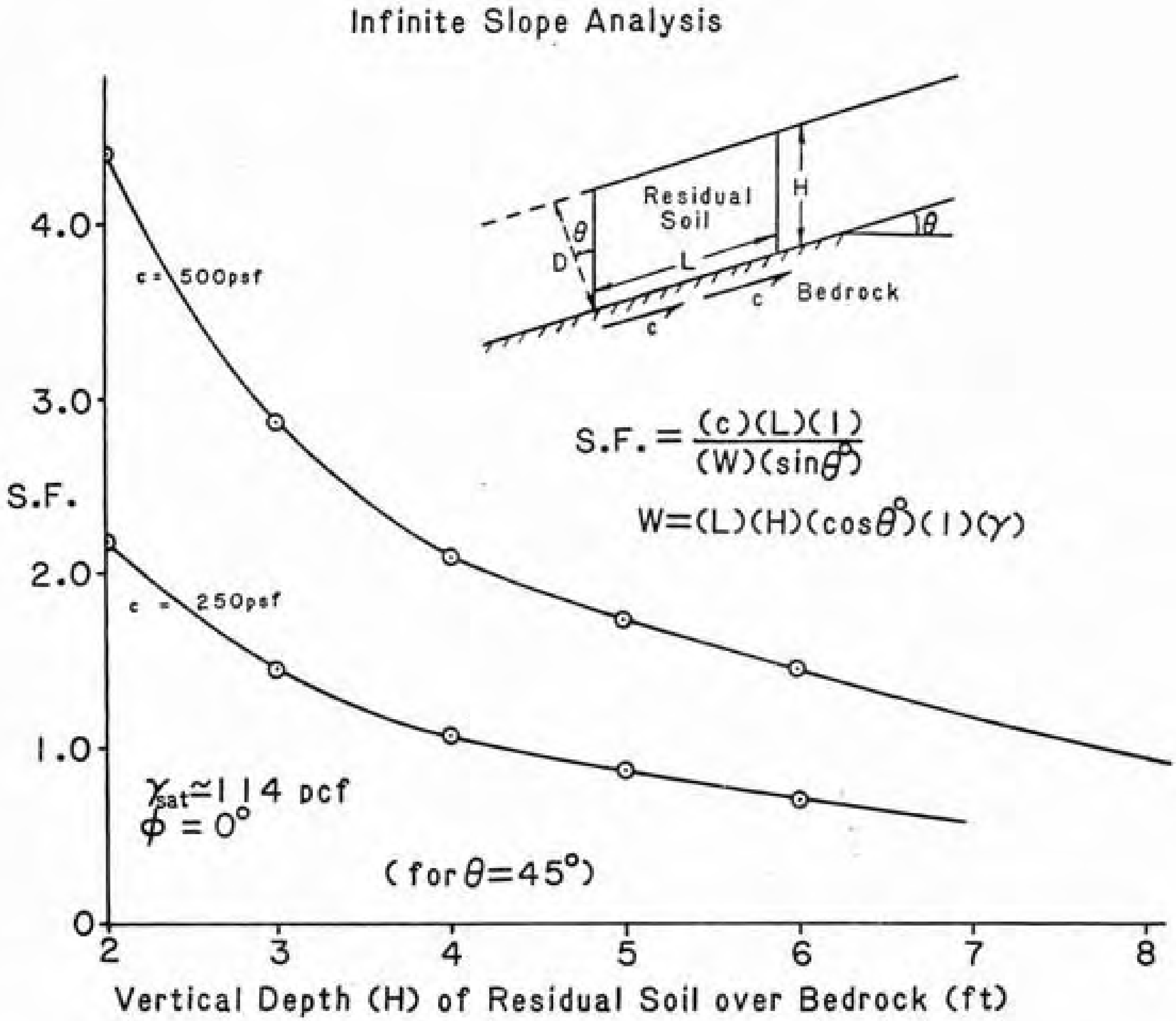
Another slope failure was observed northeast of New Bellsville where a moderately sloping (~35 degree) hillside was undercut. Sampling found bedrock at a depth of four to five feet below the surface and old scarp 12.5 feet high and 70 feet long, was observed at the crest of the slope. A similar, more recent, slope failure occurred along a small county road south of Mt. Liberty. The failure was apparently associated with a recent, severe rainfall.

A source at the Brown County Highway Department reported that most slope failures occurred after heavy rainfall, indicating that excessive water is an important mechanism contributing to slope instabilities in Brown County.

The following analysis is based upon field observations, literature data on similar clay soils and engineering judgement. The results are presented to convey a point and are not for design.

A total stress analysis was applied to the cohesive soil slopes because, in the author's opinion, there is little dissipation of excess pore pressures occurring prior to critical stability conditions. The strength of the undrained soil is represented by a cohesive shear strength and a friction angle equal to zero (see references 22; p 7-3-7, 14; p 559 for further details). The shear strength is estimated to be around 250 to 500 PSF based on personal experience and literature review. Figure 15 illustrates the type of slope configuration in which failure is likely.

The results shown on Figure 15 indicate the critical (eg., a factor of safety of one is reached and failure is imminent) soil depth (H) ranges from 4 1/2 to 7 1/2 feet (or 3 1/2 to 5 1/2 feet, depth measured normal to the surface), depending on the cohesive strength of the soil. The analysis assumes the soil has become saturated or nearly so by surface water infiltration which increases the driving force. Field observations of slope failures in residual soil found bedrock at a vertical depth of 4



Perpendicular Depth (D) = $(\cos\theta)(H)$

c – cohesion: ½ of the unconfined compressive strength (psf) estimated field and literature values (23).

γ_{sat} – based upon average dry densities (pcf) and water contents reported by I.D.M.T. (20) and SCS (9).

Figure 15 Slope Stability Analysis of Soft, Undrained Residual Soils.

to 7 feet and slope angles of about 35 to 50 degrees in the adjacent undisturbed areas. Therefore the analysis is a reasonable qualitative approximation of the actual soil configuration and soil conditions which promote failure. The main point to be drawn from the analysis is the fact that the factor of safety decreases with increasing depth of residual soil, which the analysis and field observations indicate ranges from 4 to 7 1/2 feet in depth (H).

The assumed conditions leading to failure are as follows. First, is the development of a relatively deep, cohesive, residual soil blanket over sloping bedrock. Secondly, the flow of ground water must be concentrated at the bedrock/soil interface which keeps the lower-most soil horizon at a near-saturated, soft condition. Next, the toe of the slope is cut, removing support and allowing the up-slope soil mass to act as an independent sliding mass. The final condition is the saturation of the surface soils from long duration rains. The added water weight increases the driving force towards instability and the compression of the soil below increases the saturation level. With increasing saturation, due to compression of the soil, the shear strength lowers to its ultimate value.

In conclusion, failures in residual soil slopes are more likely with increasing soil thickness. Failure is also attributed to the saturation of the upper surface during rainfalls of long duration and loss of toe support.

Rock Slopes

Rock slope instabilities are rare in Brown County. The rock strata are nearly horizontally bedded and the joints are widely spaced (3-10 feet). The rock mass quality is termed "good" by the CSIR rock mass rating system (Hoek & Bray, 31) which relates joint spacing and orientation, weathering characteristics, rock type, and rock orientation to construction problems in rock. The term 'good' means that there will be only minor problems with excavations or construction in or on the bedrock. Most joints or discontinuties are nearly vertical, ranging from 75 degrees to 90 degrees and are probably associated with the regional tectonic stresses which formed the Cincinnati arch to the northeast. The general dip direction of these joints is 140 degrees and 65 degrees based upon numerous field measurements.

Planar failures do not occur because the conditions needed for failure do not exist. The first condition is that the sliding surface 'daylight', that is, the plane projects into open spaces along the slope face (see Figure 12). The beds dip about one to two degrees to the southwest and daylight on southwest facing slopes. The second condition for failure is that the angle of friction is less than the dip of the sliding plane. The friction angle for shale (ranging from 27-35; 31) is greater than the local dip angle, meaning planar failures should not occur. Wedge failures are rare because the joints are widely spaced and the daylighting condition for failure is not met (see Figure 12).

One type of rock slope failure is common. Rock ledges or cantilevers of thin sandstone (< 1 foot) units are formed by the erosion of the surrounding shale members. The shale units weather to a greenish clay leaving the sandstone units projecting into space. The stranded rock unit eventually breaks off, sliding down into the shoulder of the highway or in the drainage ditch. Cantilevers as long as five feet were observed near the western county border. These slope failures are more common in the western portion of some of the county, where the sandstone rock units are more common.

Excavation and Foundation Problems

Most of the soils or parent materials of Brown County provide adequate foundation support for light to moderately loaded structures which predominate in the area. The two major problem areas in this respect are the lacustrine clays and the flood plain soils. The following descriptive analysis is based upon information supplied by the Brown County Highway Department, Brown County Soil Survey, and field observations. In this section, the term "soil" refers to the subsoil and parent materials below the organically rich, disturbed surface soils (6-10 inches), which are generally removed or compacted because of their inadequate shear strength and high compressibility.

Glacial Drift soils exhibit very high (6,7,10) shear strengths having estimated unconfined compressive strengths well over 1 1/2 TSF. Light buildings located on shallow foundations, 3-4 stories, just north of the county border in the town of Morganstown were observed and reported to be performing adaquately with little or no settlements (52). A brief field survey of a number of building foundations revealed a minimum number of cracks and no displacement of attached structures (such as walkway stoops) indicating sound foundation conditions. Temporary excavations rarely require bracing; and vertical, unbraced cuts as deep as 10 feet were observed to be stable in the short term.

Residual soil are classified as clay of soft to moderately stiff consistency (11). Estimated unconfined compressive strengths range from 250-500 PSF (10) for these normally consolidated deposits. Residual soils are considered to have a moderate bearing capacity (9). Slab foundations of 1-2 story residential units were observed and reported to perform well with no settlement problems. The larger, heavier structures, especially those about Nashville, are founded on bedrock, due to the small amount of excavation needed to reach bedrock. The use of bedrock support eliminates bearing capacity problems and detrimental settlements. Unconfined compressive tests run on the shale range from 5000-8000 PSF (10, 20). If bedrock is used for bearing support, it should be protected from weathering, as the shale, upon exposure to the elements, slakes and loses its shear strength (see Appendix B). Bedrock permanently below the ground water table will not be susceptible to slaking. The shallow depth to bedrock eliminates the need for deep excavations requiring bracing. Excavations as deep as five feet (eg. bedrock) were reported to be stable. Upon dessication of the exposed clay, raveling occurred due to a loss of clayeyness.

Alluvial Terraces soils, in general, have moderate to high bearing capacity (9). Light structures (1-2 stories) were observed and reported to have minor differential settlements. Differential settlements often occur when subsurface variations such as pockets of poorly graded gravel or lenses of fines in the subsoil are present. The locations of such variations require a detailed site investigation. Excavations in alluvial terraces as well as those in the flood plains are difficult to maintain during high water periods, and are subject to sidewall caving. In the cohesionless alluvial terrace soils, sloughing of the sidewalls also increases with drying out of the soil.

The lacustrine deposits are composed of moderately to highly compressible silty clays (8). These moderately plastic clays have a soft to medium consistency, indicating a low to moderate bearing capacity (9), but excessive settlements are the primary concern in Brown County. Surface loading by small-to-intermediate-sized structures may produce moderate to large settlements. Significant differential settlements of a two story structure have been reported near Nashville (49). The potential for differential settlements is highest along or near the valley walls, where there are significant textural variations, and the depth to bedrock is small and variable over a small area.

One solution to the settlement problem in lacustrine soil in

Brown County is the use of partially compensated foundations. This is where the soil is excavated to a depth such that the effective weight of the excavated soil is nearly equal to the weight of the structure. This introduces the idea that the overlying material has consolidated the soil below to a certain pressure. No further significant settlements (or consolidation) will occur until the previous or preconsolidation pressure is reached and surpassed by the added weight of the overlying structure. Partial compensation is easily accomplished by the construction of a basement, where the weight of the soil removed is greater than the weight of the added basement level (23). The use of compensated foundations has been proved successful in the reduction of settlements and increase of bearing capacity.

The use of slab or mat foundations is another method used to reduce the contact pressures, thus reducing the settlements. Other foundations such as friction piles or deep footings are not recommended because there will be practically no increase in bearing capacity or decrease in the amount of settlement (52). Pile foundations should be designed for negative skin friction. Negative skin friction occurs when the soil settles about the pile, causing a downward drag on the pile, which may induce further settlements and even structural failure.

Temporary unbraced excavations in lacustrine soils as deep as six feet have been reported to be stable in Brown County. The stabilty of excavations in clays decreases with time as the exposed soil dries out. Dessication is followed by loss of plastic character and the formation of tension cracks in the soil which extend down from the surface. Bottom heave problems in deep braced excavations have been reported in neighboring Monroe County. In unbraced excavations, sideslope stability will be the controlling factor.

Construction along the flood plain areas encounter two problems; flooding and the loose condition of the surface (< 7 feet) soils. Flooding is more frequent along the lower courses of the major stream valleys (eg. the somewhat poorly drained flood plain deposits) and causes problems with the maintenance of excavations and with basement wetness.

The surface soils of the well-drained areas along the flood plain are found in a loose condition. Blow counts (N-values) in the loamy, non-plastic soils typically range from 0 to 8 with an average of 4 (19, 20). Immediate settlements upon loading are often a problem. Unconfined compressive strengths of the more cohesive surface soils range from 0.2 to 0.7 TSF. They have a medium to soft consistency and blow counts range from 0 to 5 (20). While the surface soils in the somewhat poorly drained areas are also found in a loose condition, they generally contain a greater percentage of clay and organics, and are associated with larger settlements. Blow counts usually range from 0-5 in the surface soils of these areas.

Both soil types are underlain by stiff cohesive subsoils that have unconfined compessive strengths that range from 0.5 to

1 TSF, while blow counts for the more granular subsoil range from 5 to 23. The subsoil test data indicate relatively dense soil conditions of moderate to high bearing strength. Light structures were observed to perform adequately when supported on shallow, slab foundations. Structures with concentrated loads that are supported at the surface are susceptible to settlements due to the compression of loose surface soils. Heavier structures are usually supported on end-bearing piles, embedded in the stronger subsoils or in bedrock.

Unbraced excavations as deep as five feet have been reported (49) to be stable along well-drained flood plain areas. Braced excavations, such as cofferdams, may encounter piping problems due to the presence of fine grained sands and silt layers near the bottom of the excavation. A rise in the GWT during high water periods have caused caving problems in normally stable excavations (49, 52), and such conditions may increase the piping potential.

Other Highway Problems

Roads

Brown County is served by three state highways (S.R. 45, 46, and 135) and 613 miles of county and local roads. Many of the roads suffer from some type of highway distress due to a combination of inadequate subgrade and subbase materials, local ground water problems, and climatic conditions.

Concrete Pavements

The state highways are composed of concrete pavement which, in many areas, have been resurfaced with asphaltic materials at some later time. This resurfacing has decreased surface water infiltration which has been the major contributor to the problems experienced along concrete pavements in Brown County. The state roads, along with most of the county roads, were constructed prior to 1936 (2), at which time the knowledge of compacted soil behavior was in its infancy (14). This fact, combined with the fact that Brown County lacks adequate sources of quality aggregate for subbase use, has produced the problems which continue to plague Brown County today.

State road 135, in the northern portion of the county, crosses over Illinoian ground moraine. The subgrade consists of compacted Illinioan ground moraine (49) with a thin aggregate subbase. Inadequate bearing failures near the edge of the concrete slabs have been observed and recorded (49). Silt mounds were occasionally found near the pumping failures and were assumed to be the result of the ejection of fine grained soil from under the pavement. The pumping is most severe in moderately to somewhat poorly drained areas. The pumping problems in Brown County are not as severe or numerous as those reported in adjacent counties because of the lighter traffic loads and density.

Pumping problems are common in areas of Illinoian ground moraine in Indiana. Table 10 lists the Illinoian ground moraine deposits as having the highest percent of pumping problems per mile of road than any other soil type in Indiana. The Illinoian ground moraine deposits are highly susceptible to pumping because of the high percentage of silt-size particles of a low plasticity. The texture of soils most susceptible to pumping problems is shown on Figure 16. The starred data on Figure 16 represent the composition of Illinoian ground moraine soil samples in Brown County. In the upland glacial areas of northern Brown County the loess cover ranges from 10-20 inches (9) and contributes to the pumping problem. Current practice of reducing groundwater infiltration by sealing the expansion joints, and construction of asphalt shoulders along the sides of the roads has also helped (16, 49) to reduce pumping problems.

The other portions of the state highways are located along the flood plain areas, for the most part. The highway alignment has taken advantage of the low lying alluvial terraces, thus reducing the number of embankments needed. Pumping problems along the terraces are rare, while embankments constructed from nearby residual and flood plain soils have infrequent pumping problems.

Embankments

State roads located on the above plains are built on embankments, ranging from 5 to 10 feet above the surrounding area. Most of these embankments were constructed with excavated flood

Table 10. Summary of Pumping of Fine-Grained Material in Indiana (by Soil Type) (33).

Soil Type				Estimated Concrete Pavement								
				1943‡			1947‡			1954		
Parent Material	Class	Freezing Index*	Precipitation†	Total Miles	Miles Pump.	% Pump.	Total Miles	Miles Pump.	% Pump.	Total Miles	Miles Pump.	% Pump.
Morainal clays	CH, CL	200-400	33-36		148.5		517	168.9	32.3	837	96.7	11.5
Lacustrine clays and alluvium	CH, CL, ML	10-400	34-46		43.5		336	14.7	4.3	536	26.8	5.0
Wisconsin Drift	CL, ML	50-400	34-40		22.0		960	49.9	5.2	1169	183.4	15.7
Illinoian Drift	CH, CL, ML	10-100	40-42		12.7		200	67.3	33.1	362	150.3	41.4
Loess	CL, ML	10-100	40-44				140	0	0	223	4.4	1.9
Shale	CH, CL	10-75	42-46		17.2		130	20.8	16.0	204	34.3	16.6
Limestone	CH, CL	10-75	42-46		0.5		130	3.1	2.4	203	2.6	1.3
Sandstone	CL, ML	10-75	42-46				26	0.2	0.7	48	0	0
Outwash	ML, SF	250-400	34-36				171	0	0	262	11.2	4.2
Sands							150	0	0	236	0	0

* Mean freezing index (1948-1953).
† Average annual rainfall (inches).
‡ 1943 and 1947 surveys after Woods, Green, Sweet, and Shelburne.

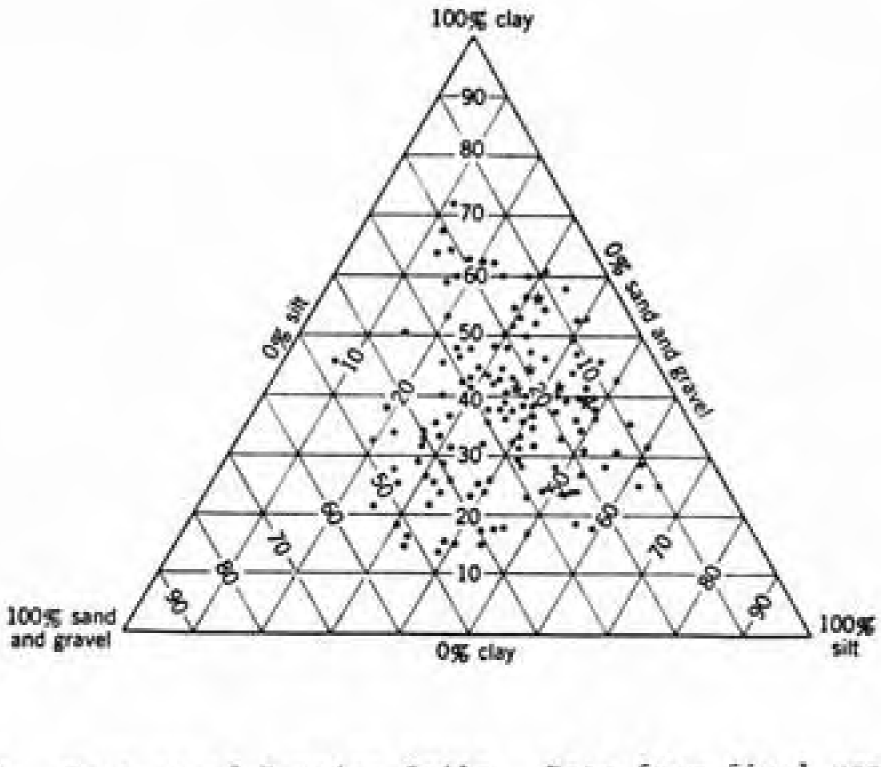


Figure 16. Texture of Pumping Soils. Data from final report of Highway Research Board Pumping Committee (33) is marked with a (.). Brown County Illinoian ground moraine soils are designated by (*).

plain materials, and soil from nearby alluvial terraces. Settlements of the embankments built on the well drained soils are low to moderate (52). Higher settlements are found along embankments built over the somewhat poorly drained flood plain deposits. An embankment along State Road 46, just east of the western county border, has produced large settlements over the last 30 years (49). The settlements have been attributed to the construction with and on the poorly drained soils of high compressibility. Sideslope instabilities of these compacted fills were not observed or reported to be a problem, but surface erodibility of the slopes were moderate to high. Flood plain soils have a low to moderate resistance to surface erosion, while the resistance of the adjacent alluial deposits are higher.

<u>Flexible Pavements and Earthen Roads</u>

Frost heave and spring breakup plague most of the local and county roads of Brown County. The composition of these roads range from a flexible pavement of macadam with a water/oil binder or asphalt to graded, compacted earth. Commonly, the local secondary roads are unimproved earth roads, sometimes covered with a thin layer of gravel.

Frost heave is most severe where there is a combination of frost susceptible soils (see Figure 17 and Table 11), a high seasonal ground water table, and a climate where there is a gradual decrease of seasonal temperatures below freezing (41). There is a high, seasonal ground water table found in the level to

Table 11. Frost Susceptible Soils (14, page 195)

Group	Frost Susceptibility or Danger	Soil
I	None	Gravel, sand, gravelly tills
II	Moderate	Fine clay (≥ 40% clay[1] content); sandy tills, clayey tills with 16% fines[2]
III	Strong	Silt, coarse clay (clay[1] content 15–25%); silty tills

Modified (22)

[1]Defined as −2 μm.
[2]Defined as −0.06 mm.

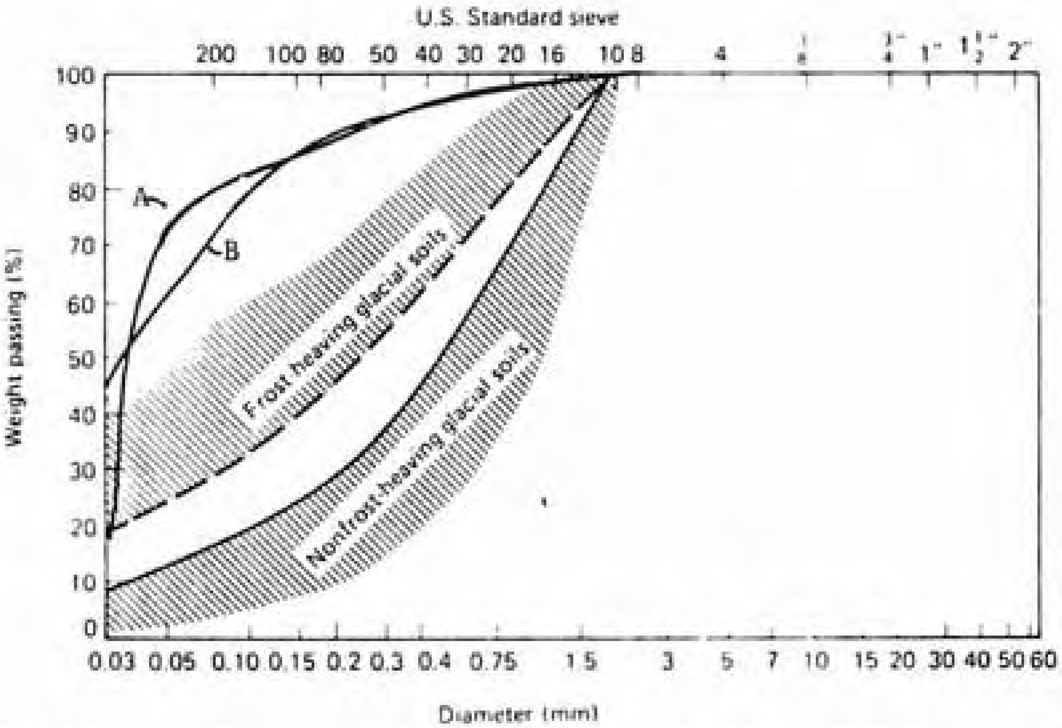


Figure 17. Limits Between Frost Susceptible and Non-Frost-Susceptible Mixtures of Glacial Tills or Similar Mixtures (14, page 194). Lines A and B represent two typical Illinoian glacial moraine soil samples from Brown County (20).

slightly rolling areas of residual and glacial soils. This condition also exists along the flood plain.

The soils which are most susceptible to frost heave are those soils which contain large percentages of silts and fine sands. In Brown County, the deposits which have this texture are the residual cohesive soils, the Illinoian drift deposits, and the flood plain areas. Those soil areas which retain their loess blanket are even more susceptible to frost heave.

The climate of Brown County is conducive to frost heave. Current climatological reports from neighboring counties and older published records of Brown County (2) indicate there is a gradual decrease in seasonal air temperatures to a mean low of 30 degrees F in December. The temperatures gradually increase in the spring from the December low. This slow increase of temperatures contributes to spring breakup of flexible pavements in Brown County. The frost depth ranged from 5 to 20 inches in 1983-84 (49), but the general design depth in Brown County is around 24 to 30 inches.

Frost damage is most severe in the Illinoian drift areas and travel along flexible and unimproved earthen roads is difficult during the spring thaw period. This requires a large amount of road maintenance every spring (eg. repatching and regrading, 49). Along more important county roads, the frost damage has been reduced by the use of thicker, better draining subbase material. Drainage of the subbase is critical in the reduction of frost heave (33, pg. 243). Brown County Lacks natural deposits of free drainage material which could be of use as a source of subbase aggregate.

Spring breakup of light flexible pavements is common along local and minor county roads where the subbase is composed of poorly compacted, weak, silty soils.

Rutting was observed along some of the secondary roads in the lacustrine terraces and residual soil areas. This is attributed to a poor subgrade (thin) and weak surface soils.

Bridges and Culverts

Bridges

Brown County contains some 74 county and state bridges (32). This count does not include numerous privately owned and constructed bridges. Fifty-eight of the bridges are single laned and are maintained by the Brown County Highway Department. The majority of these bridges were built around the turn of the century (49), but through use and age many are in need of costly repair. Estimated replacement cost was around 3.6 million dollars in 1968 (32), which has undoubtedly doubled since then. While some of the damage to these structures is attributed to normal use, most of the distress problems are due to the corrosion of construction materials and destructive forces produced by flood waters.

Stability of a bridge, large or small, is most affected by lateral forces and scour (35, pg. 503). The lateral forces considered most hazardous in Brown County are those produced from the innundation of the superstructure of the bridge by rising flood waters. Therefore, the vertical clearance of the superstructure must consider the rise in stream level during peak flow periods and any large debris transported downstream due to the increased flow. This peak flow also produces large scouring forces. These forces erode the supporting foundation material (eg. soil or bedrock) that would induce failure of the structure.

The design height of bridges in Brown County must consider the adverse flooding conditions created by major overland drainage of highly dissected bedrock topography into narrow flood plain areas. This concentration of runoff yields large peak flows that causes the increase in stream levels and erosion potential during such periods. The extremes of runoff are seen on Table 5, 6, 7. During storms of high intensity, stream flows have been known to increase by a magnitude of two, and rises in gage levels from 2 to 16 feet above normal flow heights have been measured.

The design of the state bridge along S.R. 46, east of Nashville, is an example of proper planning. The bridge has a underspan of 25+ feet and a clearance of 12+ feet over a stream which, at the time of the field trip (December, 1983), was less than 1 foot deep and 7 feet wide. This design has considered the rise of the stream level during peak flow along the north fork of Salt Creek. Gage levels, at Nashville, during peak flow periods, have been measured up to 16 feet along the Middle Fork of Salt Creek.

Scour is probably the most destructuve force affecting bridge stability in Brown County due to the large increases in stream levels and rate of flow (eg. increased erosion potential) during peak flow. A general rule of thumb when designing or investigating the depth of scour is that for each foot of rise in the stream level, scour will be twice this amount (11; pp. 409). This scour depth recommendation is applicable for unconsolidated materials. This rule is modified for the estimation of depth of scour in bedrock.

Scour depths of 1-4 feet were observed at numerous bridge locations during a field trip (April, 1984). The night before there was a heavy rainfall which caused stream levels to be elevated as much a 4 1/2 feet. A bridge failure was observed at this time along the road. The cause of failure was attributed to the collapse of the upstream, cutbank side abutment. The collapse was due to the erosion of the bedrock support below the abutment by scour. Scour had removed 2 feet of unconsolidated material (sand and gravel) and 2 1/2 feet of sound shale bedrock.

Current design practices in Brown County requires support by steel end-bearing piles to be driven to refusal. Since the unweathered bedrock has a high compressive strength (> 7000 PSF; 20), this depth of embedment may be insufficient against scour. Generally, even for small briges, the depth of embedment should be at least three feet (35, pg. 510) below the finished grade.

Culverts

Due to the high stream dissection of the bedrock areas of Brown County, numerous culverts have been constructed as an economic alternative to bridge construction for the purpose of crossing minor tributaries and streams. A sizable number of these culverts are part of large embankment structures which were constructed over steeply sloping tributaries for residential driveways. Many of the privately and publicly constructed culverts are underdesigned and have inadequate protection against clogging by debris. Since many of these smaller tributaries do not fall under the Ohio River Navigational Regulatory System, private construction, along and over these streams, is unsupervised and unregulated (49).

One of the privately owned and constructed embankments was observed to have as much as 15 feet (vertical height) of temporarily ponded water behind it. This was caused by a clogged culvert at the base of the embankment. Flood waters, for a short time, overtopped the structure, leaving gullies on the downstream slope face. Failure of such a structure, under these extreme conditions, would have constituted a real danger to any downstream structures.

In general, many of the culverts along the secondary county roads are underdesigned and have no debris barriers. Numerous county roads had stream flow running over, not under them, after or during a heavy rainfall. Many of these structures could have served their design purposes if a debris barrier had been installed. Large man-made objects and vegetative debris, which were washed downstream, clogged the entrances thus restricting flow. As a general rule a debris barrier should have a bar spacing of 1/2 to 1/3 the diameter of the culvert (27).

Water Retention Structures

It has been estimated that there are over 2000 small farm ponds in Brown County. These ponds are usually formed by the construction of a dam across a small tributary. A large majority of these ponds were created for recreational, livestock, and/or erosion control purposes. In the upland areas these ponds also serve as the water supply. A large number of these ponds are privately owned and constructed. The dams which formed the large artificial lakes (Sweetwater, Cordry, and Yellow Wood), in Brown County are under the control of the Department of Natural Resources.

Dams under 20 feet (vertical height) and whose drainage area is less then 100 acres are neither regulated nor supervised by the state or county. If requested, the Soil Conservation Service (SCS) will aid in the design of privately owned dams or will supervise the design and construction of the dam, if monies have been allotted to the project for erosion control. The two critical aspects of dam design in Brown County are the local soils used in the construction of the earthen dam, and the estimation of runoff.

Runoff in the glaciated areas is moderate. The overland drainage averages from 58-72% (27) due to gentle slope angles and the large amount of land which is farmed. The runoff in the bedrock areas is very high (65-90%) due to the steep slopes and land use. In the bedrock areas, the high runoff requires special consideration in design of the dam capacity. Generally, the SCS (3) suggests that the dam should be able to handle the runoff from a 25-year storm frequency (see Figure 18), with a freeboard height of 1-4 feet. Freeboard is the added vertical height above the high water design level, and is needed in order to provide a factor of safety from overtopping.

Impoundments in Sandstone -Shale Bedrock Areas

The materials used in the construction of these small earthen dams are usually obtained from nearby or adjacent areas, in the sandstone-shale residual soil areas. The soil is obtained by either stripping the upland areas, or using colluvial and valley fill materials. The use of sideslope soil is ill-advised as this may increase the probability of soil slope failure and possibly expose more of a permeable jointed bedrock unit. The upland residual soils are moderately compressible and have a moderate compactive shear strength (14, p. 158) but are subject to minor piping problems. The upland soils have proven to be suitable for use in small dams and in the cores of large dams (3). Unfor-

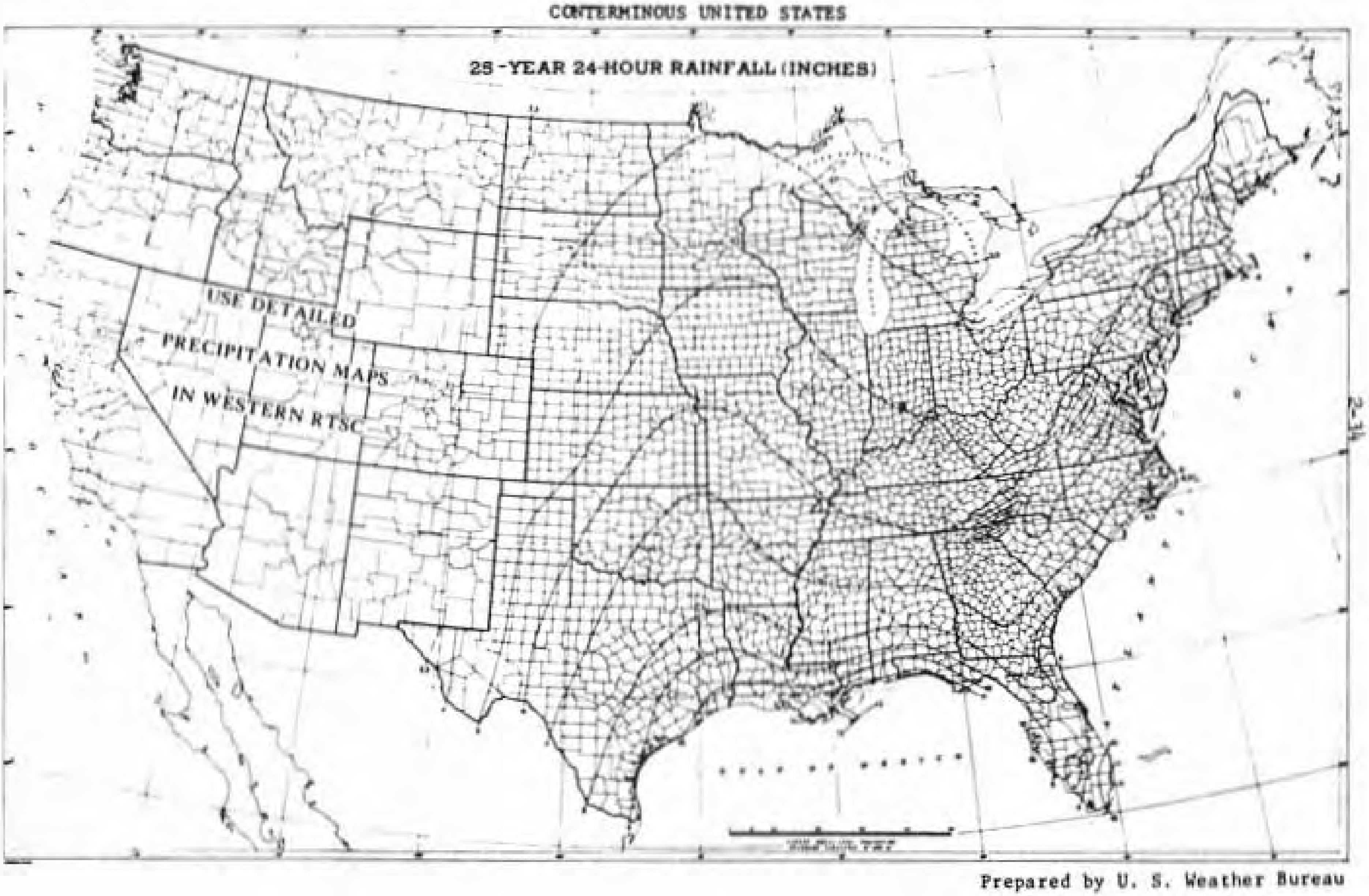


Figure 18. Rainfall Amounts from a 24-hour Storm based on 25-year Frequency. (40)

tunately, the denuding of the upland surfaces increases the surface runoff and erosion. This added runoff increases the amount of sediment transported downslope and increases the sedimentation rate behind the dam (3). This decreases the storage capacity of the pond (eg. decreased life span of the pond).

The use of valley fill and colluvial materials may alleviate the aforementioned problems associated with the denuding of the upland surfaces, but the likelihood of seepage problems occurring is much higher due to the presence of large rock fragments and gravel in the valley fill soils.

Another problem infrequently encountered in the bedrock areas is the presence of jointed rock zones or lenses of sandy residual soils along the sideslopes which cause leakage or piping actions. Leakage, due to sandy zones, which are susceptible to piping (3), usually requires the construction of a clay blanket of bentonite/soil mixture or upland residual soils. Jointing of the bedrock may cause water retention problems, but this is rarely the case. Most of the bedrock in Brown County is slightly jointed and is 'tight' (non-water bearing). The fact is evidenced by the large number of dry bedrock wells in Brown County.

Impoundments in the Glaciated Areas

In the Illinoian ground moraine areas, few problems are encountered in dam construction or performance. The surface soils, which are easily eroded and highly susceptible to piping are usually stripped off the sideslopes before construction. The subsoil is highly impermeable and is an excellent construction material for small earthen dams. For larger (20 feet in vertical height) dams, such as the Sweetwater Lake dam, this material was used in the core only because it is susceptible to surface erosion in a compacted state (34).

General Dam Stability Consideration

Most of the recorded dam failures in Brown County are due to overtopping and seepage problems. Overtopping in earthen dams is a particularly serious problem and is usually due to lack of emergency spillways (3). No SCS dam instabilities have been recorded in Brown County involving circular slope failures or overall sliding. The following design parameters (see Tables 12 and 13) are recommended by the SCS for overall sliding and circular failure of the sideslopes.

Sliding Stability

The forces which resist overall sliding of the dam due to water pressure, generated by the ponded water, are the frictional forces along the base of the dam, created by the weight of the soil fill, and the adhesion of the compacted soil along the adjacent valley walls. An increase in the factor of safety versus sliding is accomplished by increasing the top width of the dam.

Table 12.. Recommended side slopes for earth embankments (40)

Fill Material		Side Slopes Horizontal to Vertical: Upstream	Side Slopes Horizontal to Vertical: Downstream
Clay	CH	3 to 1 or 2½ to 1	2 to 1 or 2½ to 1
Clayey sand SC	Sandy clay CL		
Silty clay CL	Silty sand SM		
Clayey gravel GC	Silty gravel GM		
Silt ML or MH	Clayey silt ML	3 to 1	3 to 1

Table 13. Recommended top widths for earth embankments (40)

Height of Dam (feet)	Top Width (feet)
Under 10	~~8~~
10 to 15	10
15 to 20	12
20 to 25	14

The increase of top width is associated with an increase of a frictional strength and the surface area of adhesion. Table 13 recommends the minimum crest widths versus the dam height (the design water level is usually one to two feet below this value).

Embankment Side Slopes

The side slopes of a dam depend primarily on the stability of the material in the embankment. The greater the stability of the fill material (eg. the shear strength), the steeper the side slopes may be. The more unstable materials require flatter side slopes. Table 12 contains recommended maximum slopes for the upstream and downstream faces of dams constructed of various materials.

Waste Disposal

Only a few of the larger towns in Brown County (eg. Nashville) are served by a public sewerage system. A large majority of the county uses small septic tank absorption fields. Due to a combination of steep to rolling topography, and the very slow to moderate permeability (see Table 14) of a large percentage of soils formed in Brown County, most areas are rated moderate to severe for septic problems (48). It has been estimated that only 1-2% of the county has acceptable conditions for septic fields.

Table 14 Factors Effecting the Performance of Septic Systems

Area	% of Land by Slope Groups 0-2%	2-12%	>12%	Reported (54) Permeability % value (in/hr)	Problem Rating*
Wisconsin Drift	74	19	8	.6 - 1.25	M/H
Illinoian Drift	28	37	35	.25 - .6	H
Lacustrine Terraces	17	38	35	.5 - 1.25	M/H
Residual	5	23	72	.5 - 1.25	M/H
Alluvial Terraces	70	20	10	1 - 3	L
Flood Plains	90	8	2	10 - 12	L/M

* L-Low, M-Moderate, H-Severe. Rating for trench septic systems.

The Brown County Health Department places a 12% slope limitation on the use of trench septic systems and a minimum soil depth of 30 inches. The requirements place severe limitations on the use of trench septic systems in the Illinoian drift and residual soil areas. One method used in the residual soil areas is to pump the waste and effluent up to a more level area, where a remote trench system is constructed. This method is not feasible in the Illinoian ground moraine areas because of a second and more critical problem which plagues the septic systems. While the residual soil areas are generally not suitable for the use of local septic systems because of the steep slopes, the Illinoain ground moraine must also contend with slow to very slow permeability rates.

Many of the soils formed in Brown County have permeabilities which are termed moderately slow to very slow. The most severe absorption problems exist in the Illinoian ground moraine, followed by the residual and lacustrine soils. The Brown County

Health Department suggests the use of a dual septic system in these areas.

The combined use of the greywater and blackwater septic systems has proven to be less successful compared to the use of septic mounds (51). The use of alternating septic fields is also used with a smaller degree of success. These alternative methods have increased the percentage of land suitable for septic fields.

The problem of excessive drainage is sometimes found in the flood plain areas. Percolation values as high as 15-18 inches/hr have been found in the eastern portion of the county, where the flood plains are generally well drained. The danger that fast lateral movement of the effluent through the soil poses is a contamination of local, shallow wells which are a source of drinking water.

The use of the lacustrine terrace deposits as sanitary landfills has been considered. The moderately slow permeability of the soil and high elevation above the flood plain level make such an idea possible. However, only the deposits in the western portion of the county near Lake Monroe or Belmont possess sufficient thickness (> 20 feet) for such a use.

Summary of Engineering Problems

Table 15, p. 105, entitled "Ratings of Highway Soil Considerations for Engineering Soil Units of Brown County", contains much of the useful information collected in this study. It is particularly useful for soil engineers inexperienced with the problems of Brown County. This approach is based upon similar work by Sisiliano and Lovell (26) on the use of regional or physiographic subdivisions in the preliminary stages of planning and site investigation. Each landform has been given a general rating (L, M, or H) for a specific highway and miscellaneous construction problem. Landforms or engineering soil parent material areas, which show considerable variation in engineering properties, have been rated over a given range. Small areas which exhibit extreme textural variations and engineering behaviors were not considered in the construction of Table 15, which is based upon generalized landform-engineering soil behavior; but extreme soil variations and the problems associated with them have been discussed in the preceding specific problem descriptions.

Table 15. Rating of Highway Soil Considerations for Engineering Soil Units of Brown County

LEGEND
L(LOW)
M(MEDIUM)
H(HIGH)

PROBABILITY OF A MAJOR PROBLEM DEVELOPING

		CUT DESIGN						EMBANKMENT FILLS					EMBANKMENT FOUNDATION				SUBGRADE				FOUNDATION DESIGN							MISCELLANEOUS				
									COMPACTED PROPERTIES												SHALLOW FOOTINGS			PILES								
LAND FORM	GENERAL SOIL/ ROCK COMPOSITION	SOIL BACKSLOPE INSTABILITY	ROCK BACKSLOPE INSTABILITY	GROUNDWATER CONTROL	EROSION POTENTIAL	SURFACE DRAINAGE	NATURAL SLOPE AND RIVER BANK INSTABILITY	EROSION RESISTANCE PROBLEMS	RELATIVE PERMEABILITY	SHEAR STRENGTH INADEQUATE	COMPRESSIBILITY WHEN SATURATED	WORKABILITY PROBLEMS	EXCESSIVE SETTLEMENTS	SHEAR STRENGTH INADEQUATE	ORGANIC DEPOSIT OCCURRENCE	GROUNDWATER CONTROL	SUBGRADE SUPPORT INADEQUATE	FROST ACTION POTENTIAL	PUMPING POTENTIAL	SHRINK-SWELL POTENTIAL	INADEQUATE BEARING CAPACITY	EXCESSIVE SETTLEMENT POTENTIAL	SCOUR POTENTIAL	INADEQUATE BEARING CAPACITY	EXCESSIVE SETTLEMENT POTENTIAL	SCOUR POTENTIAL	NEGATIVE SKIN FRICTION	ESTIMATION OF LATERAL EARTH PRESSURES ON RETAINING STRUCTURES	DETRIMENTAL SHALLOW SEPTIC SYSTEM PROBLEMS	AVAILABILITY OF AGGREGATE	STEEL CORROSIVITY	CONCRETE CORROSIVITY
WISCONSIN TILL	SILT, CLAY AND SAND	L		L	L	M	L	M	L	M/L	M	M	L	L	M	M	L	M	M	M/L	L	L	L	L	L	L	L	H	M/H	L	M	M
ILLINOIAN TILL	SILT, CLAY AND SAND	L		M	M	M	L	M	L	M/L	M/L	M	L	L	L	M	L	H	H	M	L	L	L	L	L	L	L	H	H	L	M	H
THIN ILL. TILL	SILT, CLAY AND SAND	L		L	M	M	L	M	L	M/L	M/L	M	L	L	L	M	L	H	M	M	L	L	L	L	L	L	L	H	H	L	M	M
LACUSTRINE	CLAY	H		L	L/M	H	M	H	L	H/M	H	H	H	H	M	L	M	M/H	M	M	H	H	M	M	M/H	M/L	H	M	M/H	L	M	H
RESIDUAL-	SOIL-CLAY OR SAND	M/H		M	M	H	M	M	L/M	M	M	M	M	M	L	M	M/L	M	H	L/M	M	M	M	L	L	M	M	M	M/H	L	H	H
	ROCK-SH AND SS		L	L/M	L	H	L	L	M	M	L	H	L	L	L		L	L	L	L	L	L	L	L	L	L	L			L		
ALLUVIAL TERRACES	SAND, SILT, CLAY	M		M	M	M/H	M	L	M/L	L	L	L	L	L	L/M	L	L	H/M	M/L	L/M	L	L	L	L	L	M	L	L	L	M	M	H
FLOOD PLAINS	SAND, CLAY, SILT	M		L	H	L	M	M	M	M	M	M/L	M/H	H/M	M/H	L	M	H/M	M	L	H	M/H	H	M	M	H	M	M	L/M	H/M	H	M
BEDROCK BENCHES	SOIL-CLAY OR SAND	H		M	M	M	M	M	L/M	M	M	M	M	M	L	L	M/L	H	H	L/M	M	M	L	L	L	L/M	M	M	M/H	L	H	H
	ROCK-SH OR SS		L	L/M	L	H	L	L	M	M	L	H	L	L	L		L	L	L	L	L	L	L	L	L	L	L			L		

Report Summary

This report on the engineering problems associated with the engineering soil parent material areas of Brown County can lead to useful and meaningful implications and conclusions for use in preliminary stages of planning and design of highways, dams, and foundations. Its greatest potential use is for soils engineers inexperienced with the problems of Brown County. This work also represents a compiled source of pertinent engineering data of Brown County, thus making this report a ouick finger - tip reference for general engineering soil properties, shale compaction data and stream flow records.

Any unreferenced statements and conclusions made in this study represent the personal views of the writer based on his experience, and they should not be interpreted necessarily to represent the views of the Indiana Department of Highways.

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APPENDIX A

Common Soil - Landform Associations Found in Brown County.

Table A-1. Typical Agricultural Soil Series Formed Over Illinoian Glacial Ground Moraine (Thin and Thick Deposits).

[illegible] SERIES CONSISTS OF WELL DRAINED SOILS FORMED IN GLACIAL TILL ON UPLANDS. [illegible]

ESTIMATED SOIL PROPERTIES

[illegible]

THE CINCINNATI SERIES CONSISTS OF DEEP, WELL DRAINED SOILS FORMED IN LOESS AND THE UNDERLYING GLACIAL TILL ON UPLANDS. [illegible]

ESTIMATED SOIL PROPERTIES

[illegible]

[illegible] SERIES CONSISTS OF SOMEWHAT POORLY DRAINED SOILS FORMED IN LOESS AND THE UNDERLYING GLACIAL TILL. [illegible]

ESTIMATED SOIL PROPERTIES

[illegible]

APPENDIX A (Continued)

Table A-2. Typical Agricultural Soil Series Formed Over Wisconsinan Glacial Ground Moraine

[illegible]

[illegible]

[illegible]

APPENDIX A (Continued)

Table A-3. Typical Agricultural Soil Series Formed on Flood Plains in Sandstone-Shale Areas

*--THE BURNSIDE SERIES CONSISTS OF WELL AND MODERATELY WELL DRAINED SOILS FORMED IN LOAMY FRAGMENTAL SEDIMENTS ON FLOOD PLAINS. THE SURFACE SOIL IS DARK BROWN AND DARK YELLOWISH BROWN SILT LOAM 9 INCHES THICK. THE SUBSOIL IS DARK YELLOWISH BROWN SILT LOAM IN UPPER 8 INCHES AND DARK YELLOWISH BROWN FLAGGY LOAM IN LOWER 16 INCHES. THE SUBSTRATUM IS 24 INCHES OF DARK YELLOWISH BROWN FLAGGY LOAM OVER SANDSTONE. SLOPES RANGE FROM 0 TO 4 PERCENT. MOST AREAS ARE USED FOR WOODLAND.

ESTIMATED SOIL PROPERTIES

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT >3 IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-17	SIL, L	ML, CL, CL-ML	A-4	0-10	100	100	85-95	75-95	25-35	2-10
17-57	FLAGGY L, FL-SIL, FL-SIL	GC, SC, SM, GM	A-2, A-4	15-40	25-60	25-60	20-50	20-45	<28	NP-10
57-60	UWB									

DEPTH (IN.)	CLAY (PCT)	MOIST BULK DENSITY (G/CM3)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (PH)	SALINITY (MMHOS/CM)	SHRINK-SWELL POTENTIAL	EROSION FACTORS K	T	WIND EROD. GROUP	ORGANIC MATTER (PCT)	CORROSIVITY STEEL	CONCRETE
0-17	20-27	1.20-1.40	0.6-2.0	0.22-0.24	4.5-6.0	-	LOW	.37	4	5	1-3	LOW	HIGH
17-57	15-27	1.40-1.60	0.6-2.0	0.10-0.16	4.5-5.5	-	LOW	.17					
57-60													

FLOODING FREQUENCY	DURATION	MONTHS	HIGH WATER TABLE DEPTH (FT)	KIND	MONTHS	CEMENTED PAN DEPTH (IN)	HARDNESS	BEDROCK DEPTH (IN)	HARDNESS	SUBSIDENCE INIT. (IN)	TOTAL (IN)	HYD GRP	POTENT'L FROST ACTION
OCCASIONAL	BRIEF	FEB-JUN	3.0-6.0	APPARENT	FEB-JUN	-		40-60	HARD	-		B	MODERATE

*--THE STEFF SERIES CONSISTS OF DEEP, MODERATELY WELL DRAINED SOILS ON FLOODPLAINS. THEY FORMED IN ALLUVIAL MATERIAL. TYPICALLY, THESE SOILS HAVE A BROWN, SILT LOAM SURFACE LAYER 7 INCHES THICK. THE UPPER PART OF THE SUBSOIL FROM 7 TO 22 INCHES, IS BROWN SILT LOAM AND THE LOWER PART TO 46 INCHES IS LIGHT BROWNISH GRAY SILT LOAM. THE SUBSTRATUM, FROM 46 TO 56 INCHES OR MORE, IS LIGHT BROWNISH GRAY SILT LOAM. THE SUBSOIL AND SUBSTRATUM ARE MOTTLED IN SHADES OF GRAY AND BROWN. SLOPES RANGE FROM 0 TO 4 PERCENT.

ESTIMATED SOIL PROPERTIES (a)

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT >3 IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-7	SIL, L	ML	A-4	0	95-100	90-100	80-100	55-95	<35	NP-10
7-46	SIL, SICL	ML, CL, CL-ML	A-4, A-6	0	95-100	90-100	80-100	75-95	20-40	3-20
46-56	SIL, GR-L, GRSIL	ML, CL-ML, SM, GM	A-4, A-2, A-1	0-10	50-100	40-100	35-95	20-90	<35	NP-10

DEPTH (IN.)	CLAY (PCT)	MOIST BULK DENSITY (G/CM3)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (PH)	SALINITY (MMHOS/CM)	SHRINK-SWELL POTENTIAL	EROSION FACTORS K	T	WIND EROD. GROUP	ORGANIC MATTER (PCT)	CORROSIVITY STEEL	CONCRETE
0-7	12-27	1.30-1.50	0.6-2.0	0.19-0.23	4.5-7.3	-	LOW	.43	5	-	1-2	MODERATE	HIGH
7-46	12-26	1.40-1.55	0.6-2.0	0.18-0.23	4.5-5.5	-	LOW	.43					
46-56	18-27	1.40-1.65	0.6-6.0	0.08-0.22	4.5-5.5	-	LOW	.43					

FLOODING FREQUENCY	DURATION	MONTHS	HIGH WATER TABLE DEPTH (FT)	KIND	MONTHS	CEMENTED PAN DEPTH (IN)	HARDNESS	BEDROCK DEPTH (IN)	HARDNESS	SUBSIDENCE INIT. (IN)	TOTAL (IN)	HYD GRP	POTENT'L FROST ACTION
RARE-FREQUENT	BRIEF	DEC-APR	1.5-3.0	APPARENT	DEC-APR	-		>60		-		C	HIGH

*--THE STENDAL SERIES CONSISTS OF DEEP, SOMEWHAT POORLY DRAINED SOILS FORMED IN ALLUVIUM ON BOTTOMLANDS. THE SURFACE LAYER IS DARK GRAYISH BROWN SILT LOAM 18 INCHES THICK. THE SUBSTRATUM IS GRAYISH BROWN AND LIGHT GRAY MOTTLED SILT LOAM. SLOPES ARE 0 TO 2 PERCENT. CROPLAND IS THE DOMINANT USE.

ESTIMATED SOIL PROPERTIES

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT >3 IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-18	SIL, SICL	CL, CL-ML	A-4, A-6	0	100	100	90-100	70-90	25-40	5-15
18-60	SIL, SICL	CL, CL-ML	A-4, A-6	0	100	100	90-100	70-95	25-40	5-15

DEPTH (IN.)	CLAY (PCT)	MOIST BULK DENSITY (G/CM3)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (PH)	SALINITY (MMHOS/CM)	SHRINK-SWELL POTENTIAL	EROSION FACTORS K	T	WIND EROD. GROUP	ORGANIC MATTER (PCT)	CORROSIVITY STEEL	CONCRETE
0-18	18-35	1.30-1.45	0.6-2.0	0.20-0.24	4.5-6.0	-	LOW	.37	5	6	1-3	HIGH	HIGH
18-60	18-35	1.40-1.65	0.6-2.0	0.20-0.22	4.5-6.0	-	LOW	.37					

FLOODING FREQUENCY	DURATION	MONTHS	HIGH WATER TABLE DEPTH (FT)	KIND	MONTHS	CEMENTED PAN DEPTH (IN)	HARDNESS	BEDROCK DEPTH (IN)	HARDNESS	SUBSIDENCE INIT. (IN)	TOTAL (IN)	HYD GRP	POTENT'L FROST ACTION
RARE-COMMON	BRIEF	JAN-MAY	1.0-3.0	APPARENT	JAN-APR	-		>60		-		C	HIGH

APPENDIX A (Continued)

Table A-4. Typical Agricultural Soil Series Formed on Flood Plains in Glaciated Areas

* THE WILBUR SERIES CONSISTS OF DEEP, MODERATELY WELL DRAINED SOILS FORMED IN ALLUVIUM ON BOTTOMLANDS. THE SURFACE LAYER IS DARK GRAYISH BROWN SILT LOAM 9 INCHES THICK. THE SUBSTRATUM IS BROWN AND PALE BROWN MOTTLED SILT LOAM. SLOPES ARE 0-2 PERCENT. CROPLAND IS THE DOMINANT USE.

ESTIMATED SOIL PROPERTIES

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT >3 IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-9	SIL	ML, CL-ML	A-4	0	100	100	90-100	70-90	<28	3-7
9-60	SIL	ML, CL-ML	A-4	0	100	100	90-100	70-90	<28	3-7

DEPTH (IN.)	CLAY (PCT)	MOIST BULK DENSITY (G/CM3)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (PH)	SALINITY (MMHOS/CM)	SHRINK-SWELL POTENTIAL	EROSION FACTORS K	T	WIND EROD. GROUP	ORGANIC MATTER (PCT)	CORROSIVITY STEEL	CONCRETE
0-9	10-17	1.30-1.45	0.6-2.0	0.22-0.24	5.6-7.3	-	LOW	.37	5	5	1-3	MODERATE	MODERATE
9-60	10-17	1.30-1.45	0.6-2.0	0.20-0.22	5.6-7.3	-	LOW	.37					

FLOODING FREQUENCY	DURATION	MONTHS	HIGH WATER TABLE DEPTH (FT)	KIND	MONTHS	CEMENTED PAN DEPTH (IN)	HARDNESS	BEDROCK DEPTH (IN)	HARDNESS	SUBSIDENCE INIT. (IN)	TOTAL (IN)	HYD GRP	POTENT'L FROST ACTION
RARE-COMMON	BRIEF	OCT-JUN	1.5-3.0	APPARENT	MAR-APR	-		>60		-		B	HIGH

* THE HAYMOND SERIES CONSISTS OF DEEP WELL DRAINED SOILS FORMED IN ALLUVIUM. THE SURFACE LAYER IS BROWN SILT LOAM 10 INCHES THICK. THE SUBSOIL IS DARK YELLOWISH BROWN AND YELLOWISH BROWN SILT LOAM 34 INCHES THICK. THE SUBSTRATUM IS YELLOWISH BROWN FINE SANDY LOAM. SLOPES RANGE FROM 0 TO 3 PERCENT. CROPLAND IS THE DOMINANT USE.

ESTIMATED SOIL PROPERTIES

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT >3 IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-10	SIL	ML	A-4	0	100	100	90-100	80-90	27-36	4-10
10-44	SIL	ML	A-4	0	100	100	90-100	80-90	27-36	4-10
44-60	FSL, SIL, L	ML, SM	A-4	0	95-100	95-100	80-100	35-90	27-36	4-10

DEPTH (IN.)	CLAY (PCT)	MOIST BULK DENSITY (G/CM3)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (PH)	SALINITY (MMHOS/CM)	SHRINK-SWELL POTENTIAL	EROSION FACTORS K	T	WIND EROD. GROUP	ORGANIC MATTER (PCT)	CORROSIVITY STEEL	CONCRETE
0-10	10-19	1.30-1.45	0.6-2.0	0.22-0.24	5.6-7.3	-	LOW	.37	5	5	1-3	LOW	LOW
10-44	10-18	1.30-1.45	0.6-2.0	0.20-0.22	5.6-7.3	-	LOW	.37					
44-60	12-18	1.33-1.45	0.6-2.0	0.20-0.22	6.1-7.3	-	LOW	.37					

FLOODING FREQUENCY	DURATION	MONTHS	HIGH WATER TABLE DEPTH (FT)	KIND	MONTHS	CEMENTED PAN DEPTH (IN)	HARDNESS	BEDROCK DEPTH (IN)	HARDNESS	SUBSIDENCE INIT. (IN)	TOTAL (IN)	HYD GRP	POTENT'L FROST ACTION
RARE-COMMON	BRIEF	JAN-MAY	>6.0			-		>60		-		B	HIGH

* WAKELAND SERIES CONSISTS OF DEEP SOMEWHAT POORLY DRAINED SOILS FORMED IN ALLUVIUM ON BOTTOM LANDS. THE SURFACE LAYER IS BROWN MOTTLED SILT LOAM 8 INCHES THICK. THE SUBSTRATUM IS GRAYISH BROWN AND YELLOWISH BROWN MOTTLED SILT LOAM. SLOPES 0 TO 2 PERCENT. MOST AREAS ARE USED FOR CROPLAND.

ESTIMATED SOIL PROPERTIES

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT >3 IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-8	SIL	ML	A-4	0	100	100	90-100	80-90	27-36	4-10
8-60	SIL	ML	A-4	0	100	100	90-100	80-90	27-36	4-10

DEPTH (IN.)	CLAY (PCT)	MOIST BULK DENSITY (G/CM3)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (PH)	SALINITY (MMHOS/CM)	SHRINK-SWELL POTENTIAL	EROSION FACTORS K	T	WIND EROD. GROUP	ORGANIC MATTER (PCT)	CORROSIVITY STEEL	CONCRETE
0-8	10-17	1.30-1.50	0.6-2.0	0.22-0.24	5.6-7.3	-	LOW	.37	5	5	1-3	HIGH	LOW
8-60	10-17	1.30-1.50	0.6-2.0	0.20-0.22	5.6-7.3	-	LOW	.37					

FLOODING FREQUENCY	DURATION	MONTHS	HIGH WATER TABLE DEPTH (FT)	KIND	MONTHS	CEMENTED PAN DEPTH (IN)	HARDNESS	BEDROCK DEPTH (IN)	HARDNESS	SUBSIDENCE INIT. (IN)	TOTAL (IN)	HYD GRP	POTENT'L FROST ACTION
COMMON	BRIEF	JAN-MAY	1.0-3.0	APPARENT	JAN-APR	-		>60		-		C	HIGH

APPENDIX A (Continued)

Table A-5. Typical Agricultural Soil Series Formed Over Lacustrine Terrace Deposits

* THE HAUBSTADT SERIES CONSISTS OF DEEP, MODERATELY WELL DRAINED SOILS FORMED IN LOESS AND THE UNDERLYING ALLUVIUM OR COLLUVIUM ON HIGH STREAM TERRACES, VALLEY TRAINS, KAMES AND MORAINES. THE SURFACE LAYER IS BROWN SILT LOAM [illegible] INCHES THICK. [illegible] AREAS ARE USED FOR CROPLAND, WOODLAND AND PASTURELAND.

ESTIMATED SOIL PROPERTIES

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT. > 3 IN. (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

DEPTH (IN.)	CLAY (PCT)	MOIST BULK DENSITY (G/CM3)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (PH)	SALINITY (MMHOS/CM)	SHRINK-SWELL POTENTIAL	EROSION FACTORS K	T	WIND EROD. GROUP	ORGANIC MATTER (PCT)	CORROSIVITY STEEL	CONCRETE
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

FLOODING FREQUENCY	DURATION	MONTHS	HIGH WATER TABLE DEPTH (FT)	KIND	MONTHS	CEMENTED PAN DEPTH (IN)	HARDNESS	BEDROCK DEPTH (IN)	HARDNESS	SUBSIDENCE INIT. (IN)	TOTAL (IN)	HYD GRP	POTENTIAL FROST ACTION
NONE			[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]	[illegible]	[illegible]	[illegible]

* [illegible]

ESTIMATED SOIL PROPERTIES

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT. > 3 IN. (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

DEPTH (IN.)	CLAY (PCT)	MOIST BULK DENSITY (G/CM3)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (PH)	SALINITY (MMHOS/CM)	SHRINK-SWELL POTENTIAL	EROSION FACTORS K	T	WIND EROD. GROUP	ORGANIC MATTER (PCT)	CORROSIVITY STEEL	CONCRETE
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

FLOODING FREQUENCY	DURATION	MONTHS	HIGH WATER TABLE DEPTH (FT)	KIND	MONTHS	CEMENTED PAN DEPTH (IN)	HARDNESS	BEDROCK DEPTH (IN)	HARDNESS	SUBSIDENCE INIT. (IN)	TOTAL (IN)	HYD GRP	POTENTIAL FROST ACTION
NONE			[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]	[illegible]	[illegible]	[illegible]

* [illegible]

ESTIMATED SOIL PROPERTIES

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT. > 3 IN. (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

DEPTH (IN.)	CLAY (PCT)	MOIST BULK DENSITY (G/CM3)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (PH)	SALINITY (MMHOS/CM)	SHRINK-SWELL POTENTIAL	EROSION FACTORS K	T	WIND EROD. GROUP	ORGANIC MATTER (PCT)	CORROSIVITY STEEL	CONCRETE
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

FLOODING FREQUENCY	DURATION	MONTHS	HIGH WATER TABLE DEPTH (FT)	KIND	MONTHS	CEMENTED PAN DEPTH (IN)	HARDNESS	BEDROCK DEPTH (IN)	HARDNESS	SUBSIDENCE INIT. (IN)	TOTAL (IN)	HYD GRP	POTENTIAL FROST ACTION
NONE			[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]	[illegible]	[illegible]	[illegible]

APPENDIX A (Continued)

Table A-6. Typical Agricultural Soil Series Formed Over Alluvial Terraces

* - THE MARTINSVILLE SERIES CONSISTS OF DEEP, WELL DRAINED SOILS FORMED IN STRATIFIED LOAMY SEDIMENTS ON TERRACES, LAKE PLAINS, AND OUTWASH PLAINS. THE SURFACE LAYER IS DARK GRAYISH BROWN LOAM 8 INCHES THICK. THE SUBSURFACE LAYER IS YELLOWISH BROWN LOAM 5 INCHES THICK. THE SUBSOIL IS DARK BROWN CLAY LOAM IN UPPER 12 INCHES, STRONG BROWN SANDY CLAY LOAM IN NEXT 7 INCHES AND BROWN AND DARK BROWN SANDY LOAM IN LOWER 22 INCHES. THE SUBSTRATUM IS STRATIFIED FINE SAND, VERY FINE SAND, AND SILT LOAM. SLOPES RANGE FROM 0 TO 18 PERCENT. CROPLAND IS THE MAIN USE.

ESTIMATED SOIL PROPERTIES (A)

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT >3 IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-13	L, SIL	CL, CL-ML, ML	A-4	0	100	90-100	75-100	65-90	<28	3-8
0-13	FSL, SL	SM, SM-SC	A-4, A-2-4	0	100	85-100	55-85	32-50	<20	NP-6
13-32	CL, SICL, SCL	CL, SC	A-4, A-6, A-2	0	95-100	90-100	70-100	30-90	25-40	7-15
32-54	SL, L, SCL	SM-SC, CL-ML, CL, SC	A-2, A-4, A-6	0	95-100	85-100	50-85	30-75	20-30	5-11
54-60	SR-S-L	SM, SM-SC, CL-ML	A-4, A-2-4, A-1	0	95-100	65-100	45-85	10-75	<25	NP-6

DEPTH (IN.)	CLAY (PCT)	MOIST BULK DENSITY (G/CM3)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (PH)	SALINITY (MMHOS/CM)	SHRINK-SWELL POTENTIAL	EROSION FACTORS K	T	WIND EROD. GROUP	ORGANIC MATTER (PCT)	CORROSIVITY STEEL	CONCRETE
0-13	8-20	1.30-1.45	0.6-2.0	0.20-0.24	5.1-7.3	-	LOW	.37	5	5	1-2	MODERATE	MODERATE
0-13	5-15	1.33-1.50	2.0-6.0	0.12-0.16	5.1-7.3	-	LOW	.24	5	3	1-2		
13-32	20-32	1.40-1.60	0.6-2.0	0.16-0.20	5.1-6.5	-	MODERATE	.37					
32-54	15-25	1.40-1.60	0.6-2.0	0.12-0.17	5.1-6.5	-	LOW	.24					
54-60	2-20	1.50-1.70	0.6-6.0	0.06-0.17	5.6-8.4	-	LOW	.24					

FLOODING FREQUENCY	DURATION	MONTHS	HIGH WATER TABLE DEPTH (FT)	KIND	MONTHS	CEMENTED PAN DEPTH (IN)	HARDNESS	BEDROCK DEPTH (IN)	HARDNESS	SUBSIDENCE INIT. (IN)	TOTAL (IN)	HYD GRP	POTENT'L FROST ACTION
NONE			>6.0			-		>60		-	-	B	MODERATE

* - THE ELKINSVILLE SERIES CONSISTS OF DEEP, WELL DRAINED SOILS FORMED IN ALLUVIUM ON TERRACES. THE SURFACE SOIL IS DARK YELLOWISH BROWN SILT LOAM 15 INCHES THICK. THE SUBSOIL IS YELLOWISH BROWN SILT LOAM IN UPPER 25 INCHES AND YELLOWISH BROWN LOAM IN LOWER 10 INCHES. THE SUBSTRATUM IS YELLOWISH BROWN LOAM. SLOPES RANGE FROM 0 TO 40 PERCENT. AREAS ARE USED FOR CROPLAND, HAYLAND AND PASTURELAND.

ESTIMATED SOIL PROPERTIES

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT >3 IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-15	SIL	CL-ML, ML	A-4	0	100	100	90-100	70-90	<26	NP-7
15-40	SICL, SIL	CL	A-6, A-4	0	100	100	95-100	65-90	20-35	7-15
40-50	L, SCL, CL	CL, CL-ML, SC, SM-SC	A-4, A-6	0	100	90-100	75-100	45-80	20-35	5-15
50-60	SICL, SL, L	CL, CL-ML, SC, SM-SC	A-4, A-6	0	100	90-100	85-100	40-90	20-35	5-15

DEPTH (IN.)	CLAY (PCT)	MOIST BULK DENSITY (G/CM3)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (PH)	SALINITY (MMHOS/CM)	SHRINK-SWELL POTENTIAL	EROSION FACTORS K	T	WIND EROD. GROUP	ORGANIC MATTER (PCT)	CORROSIVITY STEEL	CONCRETE
0-15	7-18	1.30-1.45	0.6-2.0	0.22-0.24	5.6-7.3	-	LOW	.37	5	5	.5-2	MODERATE	HIGH
15-40	18-30	1.40-1.60	0.6-2.0	0.18-0.22	4.5-6.0	-	MODERATE	.37					
40-50	18-30	1.45-1.65	0.6-2.0	0.15-0.18	4.5-5.5	-	MODERATE	.37					
50-60	14-30	1.40-1.60	0.6-2.0	0.11-0.20	4.5-6.0	-	LOW	.37					

FLOODING FREQUENCY	DURATION	MONTHS	HIGH WATER TABLE DEPTH (FT)	KIND	MONTHS	CEMENTED PAN DEPTH (IN)	HARDNESS	BEDROCK DEPTH (IN)	HARDNESS	SUBSIDENCE INIT. (IN)	TOTAL (IN)	HYD GRP	POTENT'L FROST ACTION
NONE-RARE			>6.0			-		>60		-	-	B	HIGH

* THE PEKIN SERIES CONSISTS OF MODERATELY WELL DRAINED SOILS FORMED IN SILTY SEDIMENTS AND RESIDUUM ON ALLUVIAL TERRACES. THE SURFACE LAYER IS DARK BROWN SILT LOAM 9 INCHES THICK. THE MOTTLED SUBSOIL IS LIGHT YELLOWISH BROWN SILT LOAM IN UPPER 17 INCHES AND YELLOWISH BROWN SILT LOAM FRAGIPAN IN LOWER 18 INCHES. THE SUBSTRATUM IS PALE BROWN MOTTLED SILT LOAM. SLOPES RANGE FROM 0 TO 12 PERCENT. THESE AREAS ARE USED FOR CROPLAND, HAYLAND AND PASTURELAND.

ESTIMATED SOIL PROPERTIES

DEPTH (IN.)	USDA TEXTURE	UNIFIED	AASHTO	FRACT >3 IN (PCT)	PERCENT OF MATERIAL LESS THAN 3" PASSING SIEVE NO. 4	10	40	200	LIQUID LIMIT	PLASTICITY INDEX
0-9	SIL, L	CL, CL-ML	A-4, A-6	0	100	100	95-100	85-100	20-30	5-15
9-26	SIL, SICL	CL	A-6	0	100	100	90-100	70-100	25-40	10-20
26-44	SIL, SICL	CL, CL-ML	A-4, A-6	0	100	100	90-98	65-90	25-35	5-15
44-75	SR-FSL-SICL	CL, CL-ML	A-4, A-6	0	100	100	90-95	50-85	20-40	5-15

DEPTH (IN.)	CLAY (PCT)	MOIST BULK DENSITY (G/CM3)	PERMEABILITY (IN/HR)	AVAILABLE WATER CAPACITY (IN/IN)	SOIL REACTION (PH)	SALINITY (MMHOS/CM)	SHRINK-SWELL POTENTIAL	EROSION FACTORS K	T	WIND EROD. GROUP	ORGANIC MATTER (PCT)	CORROSIVITY STEEL	CONCRETE
0-9	15-26	1.30-1.45	0.6-2.0	0.22-0.24	5.6-7.3	-	LOW	.43	4	5	1-3	MODERATE	HIGH
9-26	25-35	1.40-1.50	0.6-2.0	0.20-0.22	4.5-5.5	-	LOW	.43					
26-44	22-30	1.65-1.80	<0.06	0.06-0.09	4.5-5.5	-	LOW	.43					
44-75	20-34	1.40-1.60	0.6-2.0	0.06-0.08	4.5-7.3	-	LOW	.43					

FLOODING FREQUENCY	DURATION	MONTHS	HIGH WATER TABLE DEPTH (FT)	KIND	MONTHS	CEMENTED PAN DEPTH (IN)	HARDNESS	BEDROCK DEPTH (IN)	HARDNESS	SUBSIDENCE INIT. (IN)	TOTAL (IN)	HYD GRP	POTENT'L FROST ACTION
NONE-RARE			2.0-3.0	APPARENT	MAR-APR	-		>60		-	-	C	HIGH

APPENDIX A (Continued)

Table A-7. Typical Agricultural Soil Series Formed Over Sandstone-Shale Areas (Slopes, Uplands, and Bedrock Benches)

[illegible]

ESTIMATED SOIL PROPERTIES

[illegible]

[illegible]

ESTIMATED SOIL PROPERTIES (a)

[illegible]

[illegible]

ESTIMATED SOIL PROPERTIES (a)

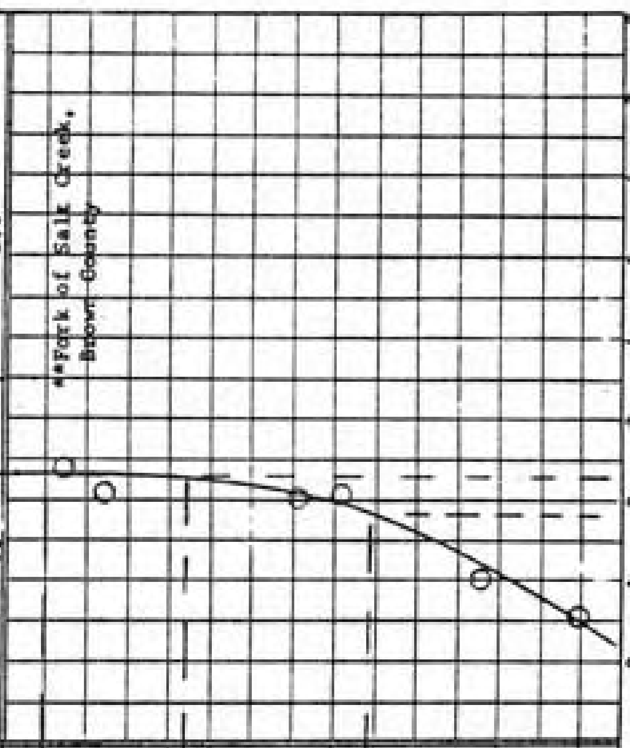
[illegible]

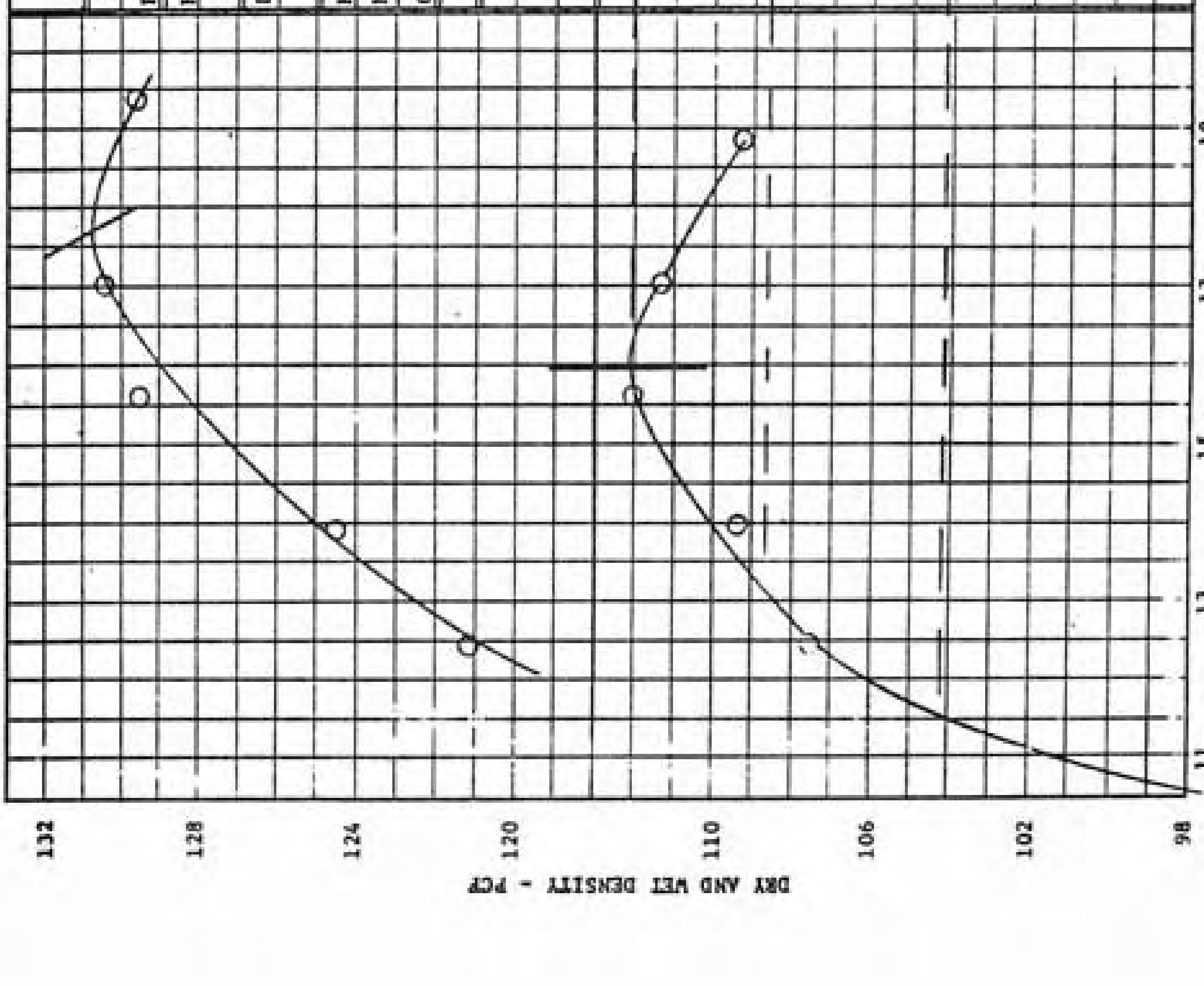
APPENDIX B

Typical Flood Plain Soil Compaction and CBR Data

Table B-1. Typical Flood Plain Soil Compaction Data (20).

MOISTURE DENSITY AND CBR SUMMARY SHEET								
H. C. NUTTING COMPANY					CINCINNATI, OHIO			
CLIENT	Indiana State Highway Commission							
PROJECT	ST Project #9999 (2), Site No. 12 (F-141-5(2)) Structure No. 135-07-6326, SR 135 Over Middle 4a							
HOLE	DEPTH	%AGG.	% CS	% FS	% SILT	%CLAY	LL	PI
RB1	5-10	14	1	3	55	27	31.7	11.4
DESCRIPTION Gray and brown SILTY CLAY LOAM						AASHTO		GI
						A-6		8
MAX. WET DENSITY, LBS./CU.FT.	30.7							
MAX. DRY DENSITY, LBS./CU.FT.	112.1							
OPTIMUM MOISTURE CONTENT - %	15.9							
PERCENT COMPACTION	CBR VALUE FROM CURVE							
100	2.3							
97	2.3							
93	1.8							





APPENDIX B (Continued)

Table B-2. Typical Flood Plain Soil CBR Data (20).

INDIANA DEPARTMENT OF HIGHWAYS
DIVISION OF MATERIALS AND RESEARCH

CALIFORNIA BEARING RATIO (CBR)
TEST REPORT

PROJ. Nº F-141-5(5) LOCATION: S.R.135 BROWN CO. BORING Nº TB-4

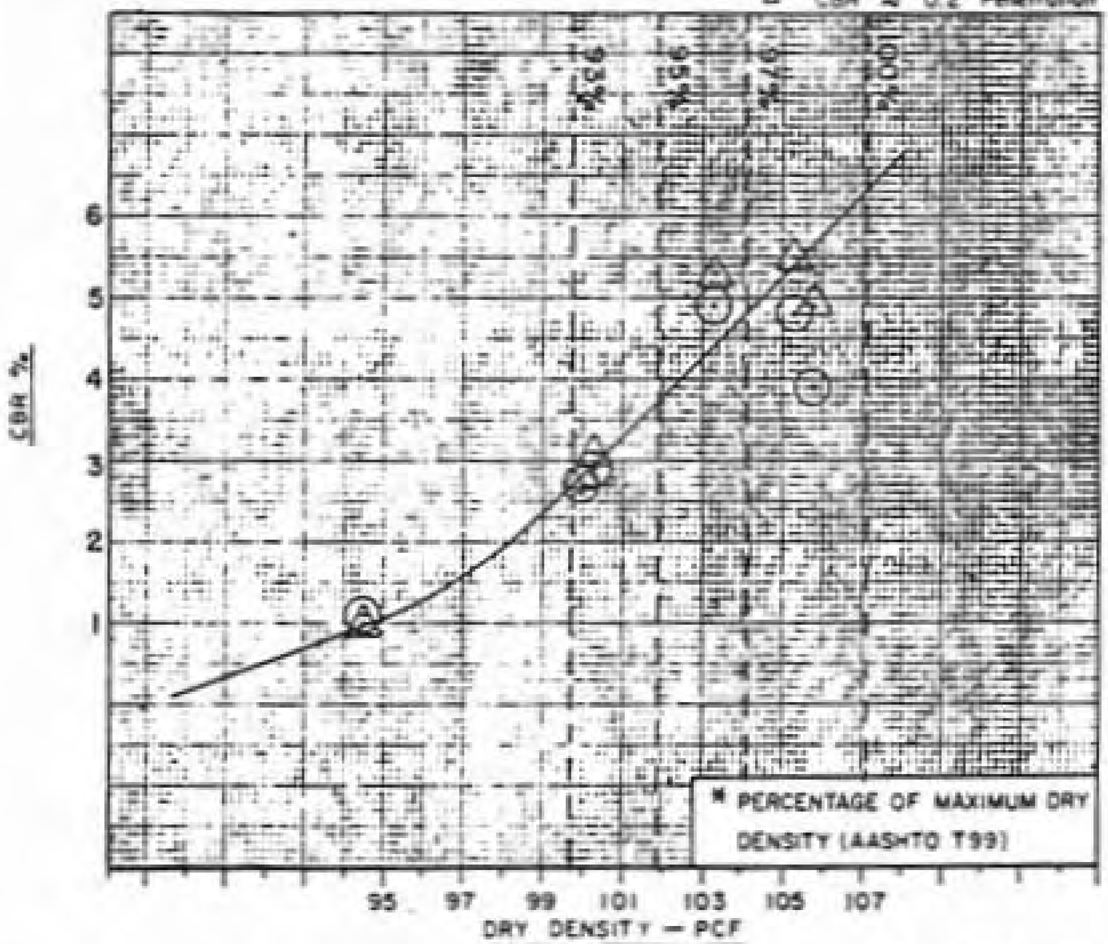
STA. 102 + 84 OFFSET 18' RT. "A" DEPTH 6.0'-7.8' LAB Nº 82-55691

CLASSIFICATION: SILTY LOAM A-4(0) MAX. WET DENSITY 125.9 pcf

2.5 % GRAVEL			MAX. DRY DENSITY 107.3 pcf
9.5 % SAND	SIEVE SIZE	% PASSING	OPTIMUM MOISTURE 17.2 %
73.7 % SILT	10	97.5	LL = N.P.
14.3 % CLAY	40	95.5	PL = N.P.
CBR At 97 % = 4.7 %	200	88.0	PI = N.P.

CBR At 95 % = 3.7 %
CBR At 93 % = 2.7 %

LEGEND: ○ CBR At 0.1" Penetration
△ CBR At 0.2" Penetration



DRAWN BY: GSC 6-29-82
CHECKED BY: TAI 6-30-82

APPENDIX C

Classification and Compaction Data for Shales Found in Brown County

Table C-1. Locust Point (Lower) Shale Classification and Compaction Data (30).

INDIANA STATE HIGHWAY COMMISSION
DIVISION OF MATERIALS AND TESTS

CONTRACT No. R-9495 PROJECT No. ST-F-63(27) ROAD No. SR-37

REPORT ON SAMPLE OF SHALE

Laboratory Number: 74-54600 County: Morgan
Quad/Date: Cope, Indiana 1965 S-SW ¼ SE ¼ NW ¼S 8 T 12N R 2E 2nd PM
Date Sampled: October 25, 1973 Date Received: October 26, 1973 Submitted by: J. Hilton
Station: 298+00 "E" Offset: 200' Rt. Depth: 40' Elevation: 640' Sample marked: --
Source of material: Borrow Pit Proposed use: Embankment

GEOLOGICAL DESCRIPTION

System: Mississippian Series: Valmeyeran Stage (Formation): Locust Point (Lower)

TEST RESULTS

GENERAL PHYSICAL DESCRIPTION

Color: Gray Hardness: Soft ☐ Medium ☐ Hard ☐; Fissility: Massive ☐ Flaggy ☐ Flaky ☐

SHALE CLASSIFICATION

Soil like ☒ Intermediate 2 ☐ 1 ☐ Rock like ☐

Slaking Index:				
Cycle No:	(1)	1.4	(5)	4.3

Slake Durability Index	200 Rev.	500 Rev.
Dry:		84.8
Soaked:		42.6

Fissility Number:
Modified Soundness Test: 84.4 % Loss

PHYSICAL PROPERTIES

Natural Wet Density:	157.5	lbs/cu.ft.
Natural Dry Density:	149.8	lbs/cu.ft.
Natural Moisture:	5.1	percent
Specific Gravity:	2.76	
Ph:	7.9	
Shrinkage Limit:	18.2	%
Lineal Shrinkage:	4.6	%
Loss on Ignition:	6.2	%

SOIL CLASSIFICATION

Textural:	Silty Clay
AASHTO:	A-4(6)
Plastic Limit:	18.9 %
Liquid Limit:	27.2 %
Plasticity Index:	8.3 %

% Sand: 8 Silt: 62 Clay: 16 Colloids: 14

Note: Clay is defined as the material below 0.005 mm.

MOISTURE DENSITY RELATIONS

(Note: Minus ☐ No. 4 ☒ ¾ inch material)

Maximum Wet Density:	140.5	lbs/cu.ft.
Maximum Dry Density:	126.7	lbs/cu.ft.
Optimum Moisture:	10.8	percent

CALIFORNIA BEARING RATIO

As Compacted CBR Value:	10.0 %
After Soaking CBR Value:	10.1 %
Average % Swell:	±.5 %

(CBR value at 95% of Maximum Dry Density)

This material is not suitable for use in embankment within two (2) feet of subgrade elevation, and disturbed shale (Uncompacted or Compacted) should not be used in cut subgrades.

APPENDIX C (Continued)

Table C-2. Locust Point (Upper) Shale Classification Compaction Data (30).

INDIANA STATE HIGHWAY COMMISSION
DIVISION OF MATERIALS AND TESTS

CONTRACT No. R-9495 PROJECT No. ST-F-63(27) ROAD No. SR-37

REPORT ON SAMPLE OF SHALE

Laboratory Number: 74-54601 County: Morgan
Quad/Date: Cope, Indiana 1965 S-SW ¼ SE ¼ NW ¼S 8 T 12N R 2E 2nd PM
Date Sampled: October 25, 1973 Date Received: October 26, 1973 Submitted by: J. Hilton
Station: 298+00 "E" Offset: 200' Rt. Depth: 25' Elevation: 655' Sample marked: —
Source of material: Borrow Pit Proposed use: Embankment

GEOLOGICAL DESCRIPTION

System: Mississippian Series: Valmeyeran Stage (Formation): Locust Point(Upper)

TEST RESULTS

GENERAL PHYSICAL DESCRIPTION

Color: Gray Hardness: Soft ☐ Medium ☐ Hard ☐ ; Fissility: Massive ☐ Flaggy ☐ Flaky ☐

SHALE CLASSIFICATION

Soil like ☒ Intermediate 2 ☐ 1 ☐ Rock like ☐

Slaking Index:				
Cycle No:	(1)	0.8	(5)	10.6

Slake Durability Index	200 Rev.	500 Rev.
Dry:		68.7
Soaked:		20.9

Fissility Number:
Modified Soundness Test: % Loss

PHYSICAL PROPERTIES

Natural Wet Density:	153.7	lbs/cuft.
Natural Dry Density:	143.6	lbs/cuft.
Natural Moisture:	7.0	percent
Specific Gravity:	2.76	
Ph:	8.0	
Shrinkage Limit:	20.0	%
Lineal Shrinkage:	2.0	%
Loss on Ignition:	4.6	%

SOIL CLASSIFICATION

Textural:	Silty Clay	
AASHTO:	A-4(7)	
Plastic Limit:	20.2	%
Liquid Limit:	28.3	%
Plasticity Index:	8.1	%

% Sand: 2 Silt: 66 Clay: 17 Colloids: 15

Note: Clay is defined as the material below 0.005 mm.

MOISTURE DENSITY RELATIONS

(Note: Minus ☒ No. 4 ☐ ¾ inch material)

Maximum Wet Density:	136.5	lbs/cuft.
Maximum Dry Density:	122.3	lbs/cuft.
Optimum Moisture:	11.2	percent

CALIFORNIA BEARING RATIO

As Compacted CBR Value:	10.5	%
After Soaking CBR Value:	2.1	%
Average % Swell:	1.1	%

(CBR value at 95% of Maximum Dry Density)

This material is not suitable for use in embankment within two (2) feet of subgrade elevation, and disturbed shale (Uncompacted or Compacted) should not be used in cut subgrades.

Table C-3. ESTIMATED RELATIVE PROPORTIONS OF CLAY MINERALS IN TEST SHALES (29).

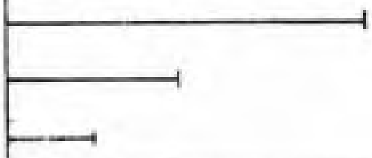
SHALE	CLAY MINERAL	RELATIVE PROPORTIONS
NEW PROVIDENCE	ILLITE	
	KAOLINITE	
	CHLORITE	

Table C-4. New Providence Shale Classification Compaction Data.

INDIANA STATE HIGHWAY COMMISSION
DIVISION OF MATERIALS AND TESTS (30).

CONTRACT No. R-8872 PROJECT No. I-265-1(1)0 ROAD No. I-265

File REPORT ON SAMPLE OF SHALE

Laboratory Number: 75-55505 County: Floyd
Quad/Date: New Albany / 1965 NW ¼ SE ¼ SE ¼S 28 T 2S R 6E 2nd PM
Date Sampled: February 21, 1975 Date Received: February 24, 1975 Submitted by: C. Andrews
Station: 116+00 Offset: — Depth: — Elevation: 575' Sample marked: Knobstone
Source of material: Cut Slope Proposed use: Information

GEOLOGICAL DESCRIPTION

System: Mississippian Series: Valmeyeran Stage (Formation): New Providence

TEST RESULTS

GENERAL PHYSICAL DESCRIPTION

Color: Grey Hardness: Soft ☐ Medium ☒ Hard ☐ ; Fissility: Massive ☐ Flaggy ☐ Flaky ☒

SHALE CLASSIFICATION

Soil like ☒ Intermediate 2 ☐ 1 ☐ Rock like ☐

Slaking Index:
Cycle No: (1) 7.9 (5) 46.3

Slake Durability Index	200 Rev.	500 Rev.
Dry:	90.7	82.9
Soaked:	66.9	45.1

Fissility Number: 15
Modified Soundness Test: % Loss

SOIL CLASSIFICATION

Textural: Silty Clay (Shale)
AASHTO: A-6(12)
Plastic Limit: 22.6 %
Liquid Limit: 33.6 %
Plasticity Index: 11.0 %
% Sand: 0.4 Silt: 60.6 Clay: 23.2 Colloids: 15.8
Clay is defined as that material smaller than 0.005 mm. dia..

PHYSICAL PROPERTIES

Natural Wet Density: 150.9 lbs/cuft.
Natural Dry Density: 139.4 lbs/cuft.
Natural Moisture: 8.3 percent
Specific Gravity: 2.78
Ph: 7.4
Shrinkage Limit: 28.7 %
Lineal Shrinkage: 2.1 %
Loss on Ignition: 3.8 %

MOISTURE DENSITY RELATIONS

(Note: Minus ☒ No. 4 ☐ ¾ inch material)

Maximum Wet Density: 133.4 lbs/cuft.
Maximum Dry Density: 120.6 lbs/cuft.
Optimum Moisture: 10.3 percent

CALIFORNIA BEARING RATIO

As Compacted CBR Value: 11.0 %
After Soaking CBR Value: 0.7 %
Average % Swell: 2.1 %
(CBR value at 95% of Maximum Dry Density)

Table C-5. Dew Providence Shale Classification and Compaction Data.

INDIANA STATE HIGHWAY COMMISSION
DIVISION OF MATERIALS AND TESTS (30).

CONTRACT No. ______ PROJECT No. ST-437(F) ROAD No. S.R. 111

REPORT ON SAMPLE OF SHALE

Laboratory Number: 76-55530 County: Floyd
Quad/Date: Louisville West/1965 SE ¼ NE ¼ SW ¼S 21 T 3S R 6E 2nd PM
Date Sampled: 3-16-76 Date Received: 3-25-76 Submitted by: C. Andrews
Station: 1097+12 Offset: 20' Lt. Line Depth: 37' Elevation: 394' Sample marked: Floyd Co. Shale #2
Source of material: Rock Core Boring Proposed use:

GEOLOGICAL DESCRIPTION

System: Mississippian Series: Valmeyeran Stage (Formation): New Providence Shale

TEST RESULTS

GENERAL PHYSICAL DESCRIPTION

Color: Gray Hardness: Soft ☐ Medium ☒ Hard ☐; Fissility: Massive ☐ Flaggy ☒ Flaky ☐

SHALE CLASSIFICATION

Soil like ☒ Intermediate 2 ☐ 1 ☐ Rock like ☐

Slaking Index:

Cycle No:	(1)	99.0	(5)	99.2

Slake Durability Index	200 Rev.	500 Rev.
Dry:		88.0
Soaked:		73.6

Fissility Number: 47
Modified Soundness Test: % Loss

SOIL CLASSIFICATION

Textural:	Silty Clay Loam (Shale)	
AASHTO:	A-4 (10)	
Plastic Limit:	22.5	%
Liquid Limit:	32.7	%
Plasticity Index:	10.2	%

% Sand: 7.2 Silt: 69.3 Clay: 16.8 Colloids: 6.7
Clay is defined as that material smaller than 0.005 mm. in diameter.

PHYSICAL PROPERTIES

Natural Wet Density:	162.0	lbs/cuft.
Natural Dry Density:	158.8	lbs/cuft.
Natural Moisture:	2.0	percent
Specific Gravity:	2.776	
Ph:	6.8	
Shrinkage Limit:	17.6	%
Lineal Shrinkage:	4.6	%
Loss on Ignition:	3.6	%

MOISTURE DENSITY RELATIONS
(Note: Minus ☐ No. 4 ☐ ¾ inch material)

Maximum Wet Density:		lbs/cuft.
Maximum Dry Density:		lbs/cuft.
Optimum Moisture:		percent

CALIFORNIA BEARING RATIO

As Compacted CBR Value:		%
After Soaking CBR Value:		%
Average % Swell:		%

(CBR value at 95% of Maximum Dry Density)

REMARKS: It is considered that this material is not suitable for use within two (2) feet of subgrade elevation.

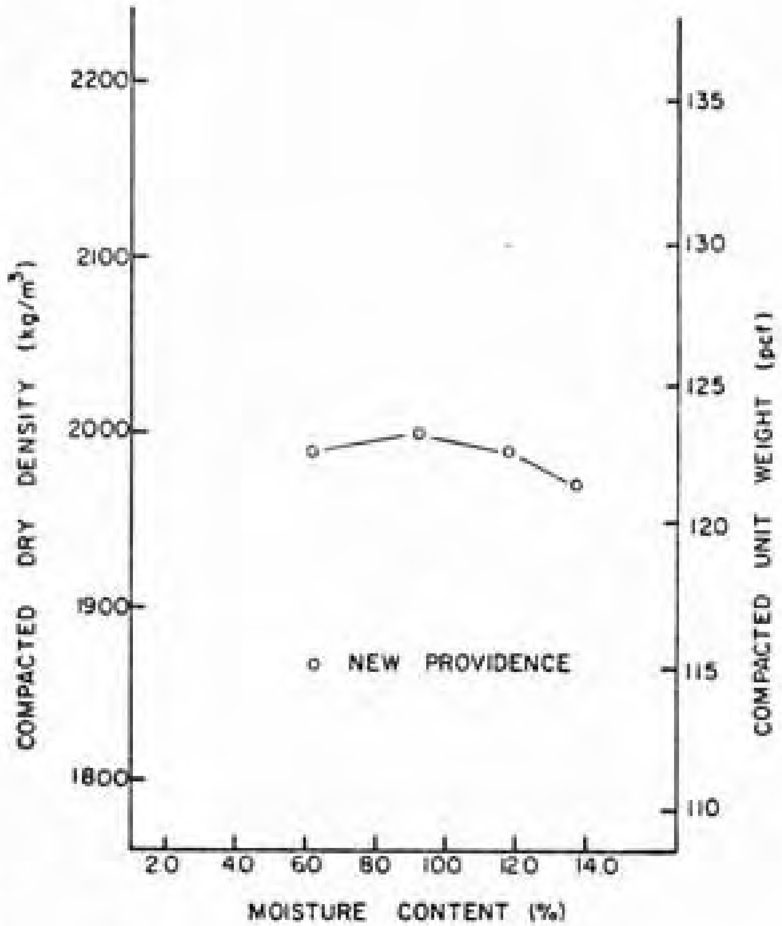


Figure C-1 EFFECT OF MOISTURE CONTENT ON COMPACTED DRY DENSITY (20).

APPENDIX D

GLOSSARY

<u>Alluvium</u> - Material, such as sand, silt, or clay, deposited on land by streams.

<u>Blackwater</u> - a type of septic system which handles the effluent from the toilets and garbage disposal.

<u>Blow Count</u> - the number of blows need to drive a soil sampler the distance of one foot (14) during a standard penetration test. This number infers the cohesive strength or relative density of the soil.

Cohesionless soils (22)

Compactness	*Very Loose*	*Loose*	*Medium*	*Dense*	*Very Dense*	
Relative density D_d	0	15%	35%	65%	85%	100%
Standard penetration resistance, N=no. of blows per foot	0	4	10	30	50	
ϕ (degrees)*		28	30	36	41	
Unit weight, pcf						
moist	<100	95-125	110-130	110-140	>130	
submerged	< 60	55-65	60-70	65-85	> 75	

*highly dependent on gradation

Cohesive soils (22)

Consistency	*Very Soft*	*Soft*	*Medium*	*Stiff*	*Very Stiff*	*Hard*
q_u = unconfined compression strength, tons per square ft	0	0.25	0.50	1.00	2.00	4.00
Standard penetration resistance, N=no. of blows per ft	0	2	4	8	16	32
Unit weight, pcf (saturated)	100-120		110-130	120-140		130+
Identification characteristics	Exudes from between fingers when squeezed in hand	Molded by light finger pressure	Molded by strong finger pressure	Indented by thumb	Indented by thumb nail	Difficult to indent by thumb nail

Coarse Textured soil - Soil containing mostly large size particles (eg., sand, gravel, or rock fragments), more than 40% by weight larger than 1/16 mm in diameter.

Colluvium - Soil material, rock fragments, or both moved by creep, slide, or local wash and deposited at the base of steep slopes.

Compaction - Densification due almost entirely to expulsion of air from the soil mass by mechanical manipulation.

Compressibility - The change of specific volume and density under pressure; reciprocal of bulk modulus.

Corrode - To eat or be eaten away gradually (as by action of rust or a chemical).

Drainage class - (natural). Refers to the removal of water from the soil. Drainage classes are determined on the basis of an overall evaluation of water removal as influenced by climate slope, and position on the landscape. Precipitation, runoff, amount of moisture infiltrating the soil, and rate of water movement through the soil affect the degree and duration of wetness. Seven classes of natural soil drainage are recognized:

Excessively drained. -- Water is removed from the soil very rapidly. The soils in this class generally are free of mottles throughout. They commonly are shallow, very porous, or on steep slopes, or a combination of these.

Somewhat excessively drained. -- Water is removed from the soil rapidly. The soils in this class generally are free of mottles throughout. They commonly are shallow or moderately deep, very porous, or on steep slopes, or a combination of these.

Well drained. -- Water is removed from the soil so readily that the upper 40 inches generally does not have the mottles or dull colors related to wetness.

Moderately well drained. -- Water is removed from the soil so slowly that the upper 20 to 40 inches has the mottles or dull colors related to wetness. The soils in this class commonly have a slowly permeable layer, have a water table, or receive runoff or seepage, or they are characterized by a combination of these.

Somewhat poorly drained. -- Water is removed from the soil so slowly that the upper 10 to 20 inches has the mottles or dull colors related to wetness. The soils in this class commonly have a slowly permeable layer, have a water table, or receive runoff or seepage, or they are characterized by a combination of these.

Poorly drained. -- Water is removed so slowly that either the soil is periodically saturated or the upper 10 inches has the mottles of dull colors related to wetness. The soils in this class commonly have a slowly permeable layer, have a water table, or receive runoff or seepage, or they are characterized by a combination of these.

Very poorly drained. -- Water is removed from the soil so slowly that free water is at or on the surface most of the time. The soils in this class commonly have a slowly permeable layer, have a water table, or receive runoff or seepage, or they are characterized by a combination of these.

Drainage, surface - Runoff, or surface flow of water from an area.

Erosion - The wearing away of the land surface by water, wind, ice, or other geologic agents and by such processes as gravitational creep.

Erosion (geologic). Erosion caused by geologic processes acting over long geologic periods and resulting in the wearing away of mountains and the building up of such landscape features as flood plains and coastal plains. Synonym: natural erosion.

Erosion (accelerated). Erosion much more rapid than geologic erosion, mainly as a result of the activities of man or other animals or of a catastrophe in nature, for example, fire, that exposes the surface.

Excess fines (in Tables). Excess silt and clay in the soil. The soil does not provide a source of gravel or sand for construction purposes.

Fine textured soil - Soil consisting of mostly clay and silt sized particles, more than 50% by weight smaller than .0074 mm in diameter.

Flood plain - A nearly level alluvial plain that borders a stream and is subject to flooding unless protected artifically.

Frost action - (in Tables). Freezing and thawing of soil moisture. Frost action can damage roads, buildings and other structures, and plant roots.

Glacial till (geology). Unsorted, nonstratified glacial drift consisting of clay, silt, sand, and boulders transported and deposited by glacial ice.

Greywater - a type of septic system which handles the effluent from the showers, sinks, etc. (non-human waste sources).

Ground water (geology). Water filling all the unblocked pores of underlying material below the water table.

Infiltration - The downward entry of water into the immediate surface of soil or other material, as contrasted with percolation, which is movement of water through soil layers or material.

Lacustrine deposit - (geology) Material deposited in lake water and exposed when the water level is lowered or the elevation of the land is raised.

Liquid limit - The moisture content at which the soil passes from a plastic to a liquid state.

Loam - Soil material that is 7 to 27 percent clay particles, 28 to 50 percent silt particles, and less that 52 percent sand particles.

Loess - Fine-grained material, dominantly of silt-sized particles, deposited by wind.

Medium textured soil - Very fine sandy loam, loam, silt loam, or silt.

Moderately coarse textured soil - Sandy loam and fine sandy loam.

Moderately fine textured soil - Clay loam, sandy clay loam, and silty clay loam.

Parent material - The unconsolidated organic and mineral material in which soil forms.

Permeability - The quality of the soil that enables water to move through the profile. Permeability is measured as the number of inches per hour that water moves through the saturated soil. Terms describing permeability are:

Very slow	less than 0.06 inch
Slow	0.06 to 0.20 inch
Moderately slow	0.2 to 0.6 inch
Moderate	0.6 inch to 2.0 inches
Moderately rapid	2.0 to 6.0 inches
Rapid	6.0 to 20 inches
Very Rapid	more than 20 inches

pH value - A numerical designation of acidity and alkalinity in soil. (See Reaction, soil.)

Point load test - The point load test involves the splitting of an axial loaded core sample (28) between two hardened steel platens. The compressive force produces a tensile failures of the specimen which can be correlated to the rock hardness and compressive strength.

Piping - (in Tables) Formation of subsurface tunnels or pipelike cavities by water moving through the soil.

Plasticity Index - The numerical difference between the liquid limit and the plastic limit; the range of moisture content within the soil remains plastic.

Plastic limit - The moisture content at which a soil changes from semisolid to plastic.

Pumping - Loss of subgrade support by the expulsion of soil and water from under the pavement when a vehicle moves by.

Reaction Soil - A measure of acidity or alkalinity of a soil, expressed in pH values. A soil that tests to pH 7.0 is described as precisely neutral in reaction because it is neither acid nor alkaline. The degree of acidity or alkalinity is expressed as --

	pH
Extremely acid	below 4.5
Very strongly acid	4.5 to 5.0
Strongly acid	5.1 to 5.5
Medium acid	5.6 to 6.0
Slightly acid	6.1 to 6.5
Neutral	6.6 to 7.3
Mildly alkaline	7.4 to 7.8
Moderately alkaline	7.9 to 8.4
Strongly alkaline	8.5 to 9.0
Very strongly alkaline	9.1 and higher

Relative Density - the ratios of the natural void ratio to the range of possible void ratios (14). Only applied to cohesionless soils (sands, gravels, and non-plastic silts).

Relief - The elevations or inequalities of a land surface, considered collectively.

Residuum - (residual soil material). Unconsolidated, weathered, or partly weathered mineral material that accumulated as consolidated rock disintegrated in place.

RQD (Rock Quality Determinate) - The combined length of rock core measuring over 4 inches in length divided by the total length of core measured. The RQD value is expressed as a percent (eg., 0-100).

Seepage - (in Tables). The movement of water through the soil. Seepage may adversely affect the specified use.

Settlements - The total vertical deformation at the surface resulting from the load is called settlement.

Shear Strength - The maximum resistance of a soil to shearing stresses. It is the result of friction between particles and cohesion.

For saturated clay shear strength the following terms are used:

Consistency	(TSF) Unconfined Compressive Strength
Very Soft	<.25
Soft	.25-.5
Medium	.5-1.0
Stiff	1.0-2.0
Very Stiff	2.0-4.0

Terrace - (geologic) An old alluvial plain, ordinarily flat or undulating, bordering a river, a lake, or the sea.

Texture, Soil - The relative proportions of sand, silt, and clay particles in a mass of soil. The basic textural classes, in order of increasing proportion of fine particles, are sand, loamy sand, sandy loam, loam, silt loam, silt, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay, and clay. The sand, loamy sand, and sandy loam classes may be further divided by specifying "coarse," "fine," or "very fine."

Toe slope - The outermost inclined surface at the base of a hill; part of a foot slope.

Topsoil - The upper part of the soil; which is the most favorable material for plant growth. It is ordinarily rich in organic matter and is used to topdress roadbanks, lawns, and land affected by mining.

Upland - (geology) Land at a higher elevation, in general, than the alluvial plain or stream terrace; land above the lowlands along streams.

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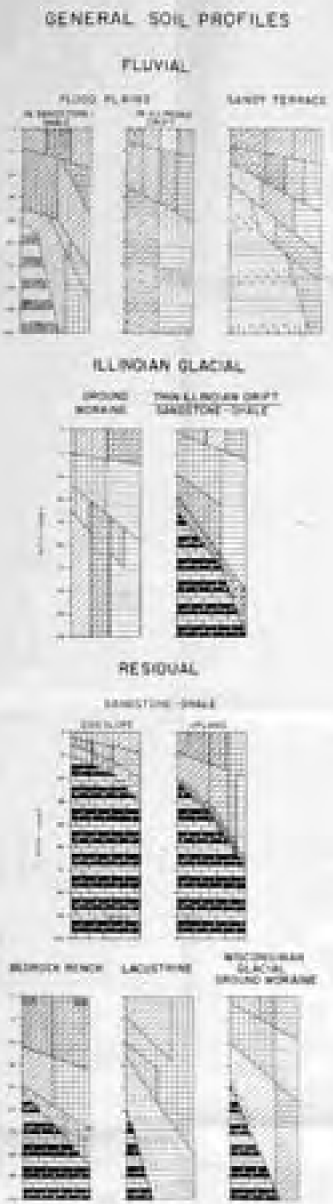


ENGINEERING SOILS MAP

BROWN COUNTY

INDIANA

PREPARED FROM

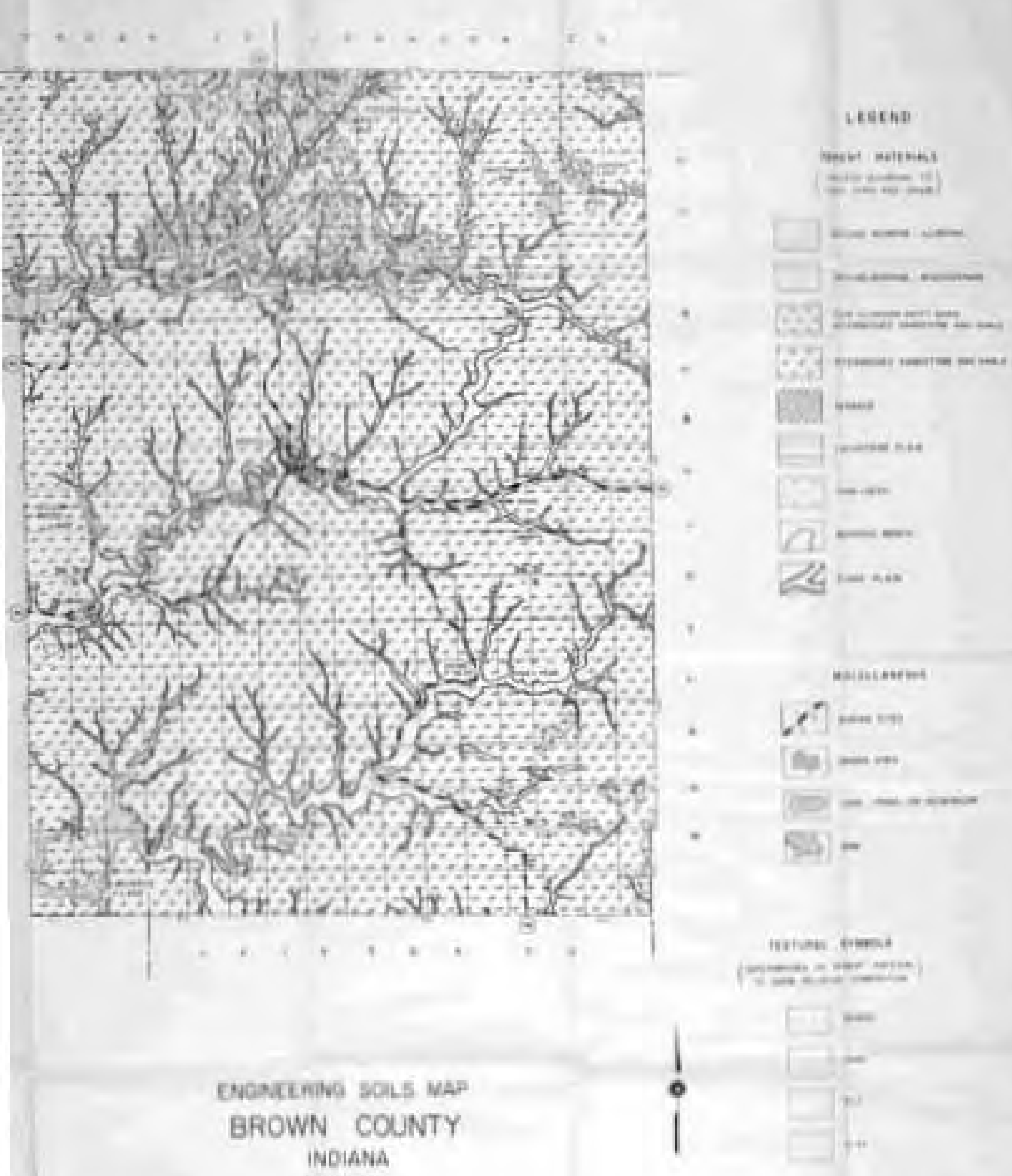
AERIAL PHOTOGRAPHS

BY

JOINT HIGHWAY RESEARCH PROJECT

AT

PURDUE UNIVERSITY



ENGINEERING SOILS MAP

BROWN COUNTY

INDIANA

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